HAND-BOOK

OF THE

OUBLE” SLIDE RULE,

SHEWING ITS APPLICABILITY TO

NAVIGATION.

INCLUDING SOME REMARKS ON GREAT CIRCLE
AND VARIATION OF THE COMPASS.
WITH USEFUL ASTRONOMICAL MEMORANDA.

BY W. H. BAYLEY,
(LATE) H.M. EAST INDIA CIVIL SERVICE

LONDON:
BELL & DALDY, 186, FLEET STREET.
1864.

HAND-BOOK

OF THE

"DOUBLE" SLIDE RULE,

SHEWING ITS APPLICABILITY TO

NAVIGATION.

INCLUDING SOME REMARKS ON GREAT CIRCLE SAILING,
AND VARIATION OF THE COMPASS,
WITH USEFUL ASTRONOMICAL MEMORANDA.

BY W. H. BAYLEY,
(LATE) H.M. EAST INDIA CIVIL SERVICE.

LONDON:
BELL & DALDY, 186, FLEET STREET.
1864.

R. CLAY, SON, AND TAYLOR, PRINTERS, BREAD STREET HILL.

PREFACE.

The object of this little work is not only to show the applicability of the "Double" Slide Rule to Navigation, but also to afford some useful explanations to the young seaman. With this view, the Definitions (p. 6), Formulæ (p. 11 and 41), remarks on Mercator's Sailing (pp. 26—30), Dip and Distance of Objects (Appendix B), Great Circle Sailing (p. 86), Variation of the Compass (p. 111), with some useful Astronomical Memoranda (pp. 113—127), and Tables (Appendix F) have been introduced.

The Slide Rule known as "Bevan's," has indeed lines of Sines and Tangents, but being on the back of one of the Slides, and so arranged that they can only be used by measurement with compasses, they are practically as useless as the old *standing* Gunter (see p. 16 and 24). To remedy this, and make these lines really useful and handy, the author of this work has had them placed on the outside of the second Slide, and so arranged the lines over and under this Slide, that no measurement is

required, and problems are solved as in the old *sliding* Gunter, with this advantage, that we have an instrument of 12 inches, much more accurate and easy to handle than the sliding Gunter of 2 feet. (See p. 56.)

This Trigonometrical Slide is also very handy in *Surveying*, as will be shown in another small treatise about to be published.

The "Double" Slide Rule has on the other face the ordinary Slide, useful in all cases of Arithmetic and Mensuration, as very fully exemplified in a former "Hand-book." But in case those who have the "Double" Slide Rule, should not possess the above work, a brief explanation of the use of the Arithmetical Slide is given in Appendix A.

The Rules are made by "ELLIOTT BROTHERS," 449, Strand. The price of the *Single* Slide Rule is 7*s.*; of the *Double*, 14*s.* The lines are very accurately laid down.

W. H. B.

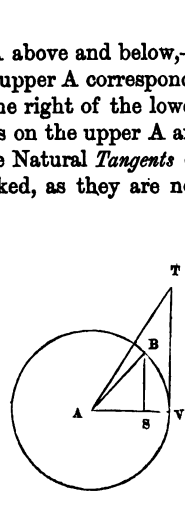
THE

"DOUBLE" SLIDE RULE.

THE "Double" or "Two Slide" Rule, has on the obverse side, the *arithmetical* Slide $\frac{\text{B}}{\text{C}}$, the uses of which are explained in APPENDIX A, and also on the reverse face, the *trigonometrical* Slide $\frac{\text{SIN.}}{\text{TAN.}}$, to which this volume is specially devoted. It will be found of the greatest service in the speedy solution of the ordinary cases occurring in SURVEYING by angular instruments, and in NAVIGATION; superseding as it does, the use of "Tables."

When the Slide is shut in even with lines A above and below,—that is, when the 1 at the extreme right of the upper A corresponds with 90° on SIN.—and when the 1 on the extreme right of the lower A corresponds with 45° on TAN.—the numbers on the upper A are the Natural *Sines*, and those on the lower A the Natural *Tangents* of the angles on the Slide. (Secants are not marked, as they are not required.)

Natural sines and tangents are expressed in terms of the *radius*. Thus in the figure, if the angle BAV = 48° 36′, the Nat. Sine, or BS, is ·750 or $\frac{3}{4}$ the radius AV, whatever may be the actual length of AV.



So again, if the angle TAV = 56° 19′, its Nat. Tan. VT is 1·5, or $1\frac{1}{2}$ times the length of the Radius AV, whatever length AV represents.

The following Note may assist the memory in the case of *Angles above* 90°:

Angle a between 90° and 180° $\begin{cases} \text{Sin. } a = \text{Sin. } (180° - a) \\ \text{Cosin. } a = \text{Sin. } (a - 90°) \end{cases}$

Angle a between 180° and 270° $\begin{cases} \text{Sin. } a = \text{Sin. } (a - 180°) \\ \text{Cosin. } a = \text{Sin. } (270° - a) \end{cases}$

Angle a between 270° and 360° $\begin{cases} \text{Sin. } a = \text{Sin. } (360° - a) \\ \text{Cosin. } a = \text{Sin. } (a - 270°) \end{cases}$

The same applies to Tangents and Cotangents, Secants and Cosecants.

SINES.

SHUT the Slide in even, as explained in the previous page, and the following Angles and Natural Sines, will be found to correspond :

Angles.	Nat. Sines.	Angles.	Nat. Sines.	Angles.	Nat. Sines.
0° 35′ =	·01018	5° 10′ =	·09005	15° 40′ =	·27004
0° 55′ =	·01600	8° 10′ =	·14205	30° 00′ =	·50000
1° 00′ =	·01745	9° 30′ =	·16505	42° 00′ =	·66913
2° 00′ =	·03490	11° 00′ =	·19081	70° 00′ =	·93969
3° 40′ =	·06395	13° 00′ =	·22495	76° 00′ =	·97209

A few of the above are engraved on the edge of the Rule, as a guide to the accurate setting of the Slide.

The Nat. Sine of 30° is always *half the Radius ;* therefore, whatever number on A is over 90°, its half should be over 30°, whether the Slide is shut in, or partially drawn out; and it is as well always to remember this, as it is a good check to accurate setting, in all problems where the line of SINES is used.

It will be observed that the Slide does not extend far enough to the left, to admit of the use of a smaller angle than 0° 34′ 22″, the Nat. Sine of which is ·010 or $\frac{1}{100}$th of the Radius ; but this is of no consequence in practice.

In the best Rules, there is an extra line of Sines on the *back* of the Slide, arranged so as to give more space to the divisions, and therefore more accuracy in taking out. This is effected by commencing with 5° 44½′, (the Sine of which is ·1, or $\frac{1}{10}$th of the Radius,) and using it with a line D of single Radius engraved under it. Of course it does not suit angles less than 5° 44½′, and it cannot be used in conjunction with either of the lines marked A.

TANGENTS.

SHUT the Slide in even, as explained in page 1, and the following Angles, and Natural Tangents, will be found to correspond:

Angles.	Nat. Tan.	Angles.	Nat. Tan.	Angles.	Nat. Tan.
0° 35′ =	·01018	6° 10′ =	·1080	23° 00′ =	·4247
1° 50′ =	·03201	13° 00′ =	·2309	27° 00′ =	·5095
3° 50′ =	·06700	16° 10′ =	·2899	35° 00′ =	·7002
4° 00′ =	·06993	18° 00′ =	·3249	45° 00′ =	1·00

Some of these are engraved on the edge of the Rule, as a guide to the accurate setting of the Slide.

It will be observed that the Slide does not extend far enough to the left, to admit of the use of a smaller angle than 0° 34′ 23″, the Nat. Tan. of which is ·010, or $\frac{1}{100}$th of the Radius; nor does it extend far enough to the right to admit of a larger angle than 45°, which is equal to Radius, or 1·00.

The first deficiency is of no consequence in practice. As to the second, all the ordinary problems in Navigation (to which the Slide Rule is particularly suited) are worked without exceeding an angle of 45° or 4 Points. However, on the best Rules, there is an *extra line of Tangents* on the back of the Slide, which being shut in even with the line A of the lower stock, provides for all the angles between 5° 43′,* (the Nat. Tan. of which is ·100, or $\frac{1}{10}$th of the

* Half a Point of the Compass is 5° 37′ 30″.

Radius),—and 84° 18′, (the Nat. Tan. of which is 10·00, or 10 times the Radius). Thus we shall find

Angles.	Nat. Tan.	Angles.	Nat. Tan.
49° 00′ =	1·150	76° 20′ =	4·112
58° 00′ =	1·600	80° 50′ =	6·197
66° 30′ =	2·300	83° 40′ =	9·010

The method, (when there is *no* extra line of Tangents), of operating with Tangents of Angles above 45°, is as follows: Set the *complement* of the given angle over the 1 on the extreme left of the line A of the lower stock, and under 45° on the line TAN. will be found on A, the Nat. Tangent required. If the Nat. Tan. given is above 1·00, and its angle required, the operation is reversed.

Example. What is the Nat. Tan. of 80° 50′? (Its *complement* being 9° 10′).

TAN	9° 10′ = compl. of given angle	45°
A	1	6·20 Ans.

Example. What is the angle corresponding to a Nat. Tan. of 1·68?

TAN	30° 45′ is compl. of Answer 59° 15′	45°
A	1	1·68

By this method, we can deal with angles even above 84° 18′, (which is the limit of the extra line referred to in page 3, though in practice, Tangents above 84° are not required), as follows:

Example. What is the Nat. Tan. of 88° 50′?

TAN	1° 10′ = compl. of given angle	45°
A	1	49·1 Ans.

There is still another method of operating with Tangents of angles above 45°, which if there is *no* extra line of Tangents on the back of Slide, may be useful, when several have to be taken out together. It is as follows: Take out the Slide; turn it upside down, and shut it in with the line TAN. *inverted,* under the line A of the upper stock; then over the *complements* of the given angles, are their Natural Tangents. The 1 on the extreme left of the line A is then 1·00; that in the middle is 10·00; that at the extreme right is 100.

COTANGENTS.

THESE are taken out as the Tangents of the *complements* of the given angles. Thus the Cotangent of 48° is the same as the Tangent of 42°, namely ·900. The angle corresponding to a Cotangent 2·3 times the Radius, is obtained by first finding the Tangent, namely 66° 30′, —the complement of which, or Cotangent required, is 23° 30′.

SECANTS.

SECANTS and Cosecants, though very useful in Logarithmic computation, are not required with the Slide Rule. If we have $x = \frac{\sin. a \times \sin. b}{\sin. c}$, it is more convenient in Logarithms, to put it as $\sin. a \times \sin. b \times \text{coseo.}\ c$; but two multipliers, and one divisor, are easier on the Slide Rule than three multipliers. See 5th Example in APPENDIX A; and $x = a \times \sec. b$ by logarithms, is on the Slide Rule just as easy, in the form $x = \frac{a}{\cos. b}$.

If we *want*, however, to take out Natural Secants, they may be found as the *reciprocals of Cosines*, because $sec.\ a = \frac{1}{cos.\ a}$. Take out the Slide and *invert* it, setting 90° of the line marked SIN. over the 1 on the extreme left of the line A on the lower stock. Then the numbers on the line A become a series of Secants of the *complements* of the angles over them. The 1 on the extreme left of the line A, is then 1·00; that in the middle is 10·00; and that at the extreme right is 100.

Example. What is the Secant of 16°?

: NIS	90°	74° or compl. of given angle
A	1	1·04 Answer

that is, the Secant of 16° is 1·04 times the Radius.

Example. What is the Secant of 72° 20′ ?

: NIS 90°		17° 40′ or compl. of given angle
A 1		3·29 Answer

COSECANTS.

THESE as shewn under the head of Secants, page 7, are not required in using the Slide Rule. They *may*, however, be found,—since $cosec.\ a = \frac{1}{sin.\ a}$,—by *inverting* the line marked SIN. and placing it even, over the lower line A. Then the numbers on the line A, become a series of Cosecants to the angles over them.

Example. What is the Cosecant of 21° ?

: NIS 90°		21°
A 1		2·79 Answer

NAVIGATION.

THE Points, half-Points, &c. marked on the Compass card, are called *Rhumbs.*

"*A Rhumb line,*" is any line which crosses every Meridian at the same angle, and since the Meridians converge to the Poles, it follows that such a line, must be—except when it is actually along the Equator—more or less of a curve.

"*Sailing on a Rhumb,*" is the usual method of sailing from one place to another, on the same Compass point the whole way; whereas in what is called "Great Circle" Sailing, the Compass course

varies every instant. In sailing on a Rhumb, the actual distance (except when sailing due N. or S.,—or due E. or W. on the equator,) between two points, is from 1 to 4 per cent. greater than in Great Circle Sailing, but as this last is somewhat complicated, and seldom used by seamen, except in extreme cases, it will only be referred to in this work in APPENDIX D.

"*The Nautical Mile*," or "knot," is the "Geographical mile" of 6076 feet. The Equatorial diameter of the Earth is 7925·6 miles, and the Polar diameter 7899·2, or the Equatorial mile 6086·4 feet, and the Polar, or Latitude mile, 6066·1 feet; giving a *mean* of 6076·2 feet. By the Polar or Latitude mile, is meant the *mean* of the Latitude miles, for they slightly differ in extent, as will be observed under "Difference of Latitude." It is generally stated that the Nautical Mile is $\frac{1}{60}$th of a Degree of Latitude in Lat. 45°, or $\frac{364540}{60}$ = 6075·7 feet, which is in fact the same as above. One ″ of *arc*, on the surface of the Earth, = 101·3 feet.

The following Formula is useful on the Slide Rule, when it is required to reduce one to the other:—

A	69·1	1·15	23	Statute miles
B	60	1	20	Nautical miles

"*The Nautical distance*," is the distance between two places, in Nautical miles, as measured on the Rhumb line. It is rather more than the distance by "Great Circle" Sailing (APPENDIX D), but it is what is meant by "Distance," in Log-books, Charts, &c.

"*The Difference of Latitude*," is the number of Nautical miles that one place is north or south of another. The nautical mile is, as before stated, 6076 feet, or $\frac{1}{60}$ of a degree of Latitude, in Lat. 45°, which is taken as a *mean*, but does not differ sensibly from $\frac{1}{60}$ of a degree in *any* Latitude. Strictly speaking, a mile of Latitude starting from the Equator, is 6046 feet. and in Lat. 60°, 6092 feet.

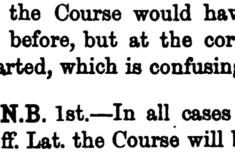
"*The Difference of Longitude*," is the number of minutes of Longitude between two places. On the Equator a minute or mile of Longitude, is 6086 feet, gradually diminishing towards the Poles, where there is no Longitude at all. It is evident, therefore, that to give the Diff. Long. between two places, is by no means giving

the distance, either in Nautical or Statute miles, that one is E. or W. of the other. To obtain this, a reduction is necessary, according to the Latitude of the place, as explained under "PARALLEL SAILING."

"*The Departure*" is the distance in Nautical miles (not in miles of Longitude) that one place is E. or W. of another.

"*The Course*" is always reckoned (in Degrees, or in Points) *from the North or South*, towards the East or West. A Table of Points, ½ and ¼ Points with their corresponding Degrees, is given in APPENDIX F, among "Useful Tables," and also engraved on the Slide Rule.

Beginners are very apt to make a mistake, and to fancy that (for instance) because a N.N.E. course is a *two* point course, an E.N.E. course is a two point course also; whereas it is a *six* point course (counting from North). In drawing Diagrams, it should always be remembered, when the Diff. Lat. and Departure are given, to draw the Diff. Lat. first, as a perpendicular up or down, or Meridian line, and *then* the Departure, or horizontal line. If the Course and Distance are given, draw a Meridian line, and protract the angle from this, (from the *top* of it, if there is any Southing), and not from any horizontal line. Thus, let a vessel from A, make 106 miles of Northing, and 256 of Easting or Departure; draw AB *first*, = 106, and then BC = 256, and join AC. Then the angle BAC (67½°) is the Course. If the horizontal line AD had been drawn first, and *then* DC, the angle of the Course would have been ACD, of the same value (67½°) as before, but at the corner *opposite* that from which the vessel started, which is confusing.



N.B. 1st.—In all cases where the Departure is greater than the Diff. Lat. the Course will be *large; i.e.* above 45° or 4 Points.

N.B. 2d.—If the Departure is divided by the Diff. Lat., the quotient is the Natural Tangent of the Course. Thus in the above case 256 ÷ 106 = 2·415, which is the Nat. Tan. of 67° 30′.

"*The Log-line*" varies in length according to the number of seconds that the Glass runs. The "Proportion" is as follows:

$$\left.\begin{matrix}\text{Sec. in 1 hour}\\ 3600\end{matrix}\right\} : \left.\begin{matrix}\text{Ft. in 1 Naut. mile}\\ 6076\end{matrix}\right\} :: \text{Sec. in Glass} : \text{Ft. in Line.}$$

And since 3600 and 6076 are *constant*, and 3600 ÷ 6076 = ·590, the number of feet in the Log-line always = Sec. in Glass ÷ ·590. For a half-minute Glass, this gives 50·6 feet; but to allow for the stretching that takes place, 50 feet is the usual measure for the Line when dry. The following Formulæ are useful for the Slide Rule:

(1)	A	1	Feet of Log-line
	B	·6	Seconds in Glass

(2)	A	Seconds in Glass	Feet run out
	B	·6	Knots per hour, or Distance

Example. What number of feet should there be in a Line for a 28 *s.* Glass, a 30 *s.* Glass, and a 32 *s.* Glass?

(1)	A	1	46·7 ft.	50	53·33 ft.
	B	·6 (Divisor)	28	30	32

Example. A ship is reported as sailing 5 knots; but the line is 45 ft. and the Glass is found to run only 25 seconds; how many knots an hour is her real rate?

(2)	A	25 seconds	5 × 44 = 225 ft. run out*
	B	·6 (Divisor)	5·4 knots

Example. If a vessel is recorded as having run 218 miles in a certain time, and both the Glass and the Line are faulty; the Glass being 31 sec. and the line 53 ft; what has been the real Distance run?

(2)	A	31 seconds	218 × 53 = 11554 ft. run out
	B	·6 (Divisor)	224 miles

For definitions of "Plane Sailing"—"Parallel Sailing"—and "Mercator's Sailing," see under the different heads. For "Dip," "Distance of Horizon," "Refraction," "Sidereal Time," see Appendices B and F.

* Multiplications are performed with lines A and B, as in Appendix A, Ex. 1.

PLANE SAILING.*

The Earth is considered to be a Plane, and all the Meridians parallel. This supposition, though incorrect, leads to no error as far as the Distance—Diff. Lat.—and Departure are concerned. The Diff. Long. is not an element in Plane Sailing, which is adapted only to small distances, such as, Bays, Channels, &c., but it is to be remembered that the other Sailings—after a slight correction is made, are resolved into Plane Sailing, which must be studied as the foundation of all.

All cases are solved by Right-angled Triangles ; the hypothenuse being considered the *Distance ;* the base or horizontal line the *Departure ;* the perpendicular line the *Diff. Lat. ;* and the angle opposite the Departure, the *Course.*

"Proportions" for Plane Sailing.

(a) In all cases except where only Diff. Lat. and Dep. are given.

Dist. : Rad. :: Departure : Sin. Course

Dist. : Rad. :: Diff. Lat. : Sin. Co-course

A	**Departure**	**Diff. Lat.**	**Distance**
SIN	**Course**	**Co-course**	**90° = Radius**

(b) Where only Diff. Lat. and Dep. are given. Take whichever is greatest, as Radius or Tan. 45°.

Diff. Lat. : Rad. :: Departure : Tan. Course

Departure : Rad. :: Diff. Lat. : Tan. Co-course

TAN	**Course**	**45° = Radius**
A	**Departure**	**Diff. Lat. (if greater)**
TAN	**Co-course**	**45°**
A	**Diff. Lat.**	**Departure (if greater)**

The learner should know how to alternate or reverse these Proportions ; so if *Diff. Lat.* is required as the last term, Rad. : Dist. :: Sin. Co-course : Diff. Lat. If *Departure* is required, Rad. : Dist. :: Sin. Course : Dep. If *Distance* is required, Sin. Course : Departure :: Rad. : Dist.; or, Sin. Co-course : Diff. Lat. :: Radius :

---

* Problems in Current and Windward Sailing,—Taking a Departure,—Shaping a Course,—Chasing, &c., are Plane Sailing, in so far that the surface of the Earth is considered a Plane ; but because they are solved by *oblique* angled Triangles, they are generally classed (after Mercator's Sailing) as "Oblique Sailing."

Distance, &c. (The Slide Rule Formula above, shews these mutations well.)

The following is a synopsis of the only 7 Cases that can occur in "Plane Sailing," with the numbers of the *Examples* that illustrate them. The Formulæ in the last column, are simply the "proportions" reduced to the form of $d = \frac{b \times c}{a}$, in case it may be wished to work with Natural Sines and Tangents as in the N.B. to Ex. 1, where $a=1$.

Cases under (*a*), page 10.

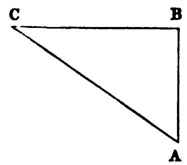
Ex.	Given	Required	
1.	Course Distance	Departure Diff. Lat.	= Distance × Sin. Course = Distance × Sin. Co-course
2.	Course Departure	Diff. Lat. Distance.	$= \frac{\text{Dep.} \times \text{Sin. Co-course}}{\text{Sin. Course}}$ = Dep. ÷ Sin. Course
3.	Course Diff. Lat.	Departure. Distance.	$= \frac{\text{Diff. Lat.} \times \text{Sin. Course}}{\text{Sin. Co-course}}$ = Diff. Lat. ÷ Sin. Co-course
4.	Distance Departure	Course Diff. Lat.	Sin. Course = Dep. ÷ Dist. = Distance × Sin. Co-course
5.	Distance Diff. Lat.	Course Departure	Sin. Co-course = Diff. Lat. ÷ Dist. = Distance × Sin. Course

Cases under (*b*), page 10.

6.	Diff. Lat. (greater) Departure	Course Distance	Tan. Course = Dep. ÷ Diff. Lat.
7.	Departure (greater) Diff. Lat.	Course Distance	Distance { =Dep. ÷ Sin. Course =Diff. Lat. ÷ Sin. Co-course }

In the following Diagrams, BC is always the "Departure," and the angle A opposite to it, is the "Course." AB is "Diff. Lat." AC the "Distance."

Ex. 1.—A ship from Lat. 52° 6′ N. sails N.W. b W. 229 miles. Required her present Latitude, and Departure made good.*



Here, Rad. : Dist. :: Sin. Co-course : Diff. Lat.
And, Rad. : Dist. :: Sin. Course : Departure

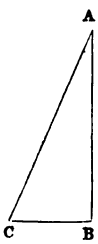
A	127 = AB	190·4 = BC	229 = AC
SIN	33° 45′ = Co-course	56° 15′ = Course	90°

Then Lat. 52° 6′ N. + 2° 7′ = 54° 13′ N. Lat. come to; and Departure 190·4 miles.

N.B. 1st.—Using Nat. Sines (col. 4 in previous Table), we have 229 × ·556 = 127 Diff. Lat. and 229 × ·8315 = 190·4 Departure.

N.B. 2d.—If the course is 45°, the Diff. Lat. and Departure are equal.

Ex. 2.—A ship from Lat. 51° 15′ N. sails SS.W. till she has made 250 miles of Departure. Required her present Latitude, and Distance sailed.



Here, Sin. Course : Dep. :: Sin. Co-course : Diff. Lat.
And, Sin. Course : Dep. :: Radius : Distance

A	250 = BC	604 = AB	653 = AC
SIN	22° 30′ = A	67° 30′ = C	90°

Then Lat. 51° 15′ − 10° 4′ = 41° 11′ N. Lat. come to; and 653 miles Distance.

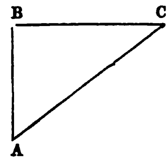
---

* It will be observed how speedily the Slide Rule, in the first 5 of these Examples, *i. e.* in all cases under (*a*), page 10, solves *both* proportions at one setting of the Slide. The Slide Rule will generally read the Course to within 10′ (which is more than the usual Tables will do), and the Diff. Lat., Dep., and Distance, to a mile, if the number is not above 300. Compare this with the method by "Gunter's Scale" as given in Norie, &c. See pages 16 and 24.

Ex. 3.—A ship sails N.E. b. E. from Lat. 42° 25′ N. till by observation, she is in Lat. 46° 20′ N. Required the Distance run, and Departure made good.

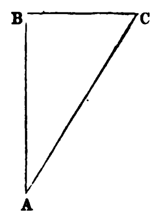
Here Sin. Co-course : Diff. Lat. : : Sin. Course : Dep.
And Sin. Co-course : Diff. Lat. : : Radius : Dist.

A	235 = A B	352 = B C	423 = A C
SIN	33° 45′ = C	56° 15′ = A	90°



N.B.—This problem suits "Heights and Distances," when the angle C is taken, and considered the *Co-course*, and CB measured as the Departure or Base. The Height BA is the "Diff. Lat."

Ex. 4.—A ship from Lat. 54° N. sails 350 miles between North and East, and finds she has made 220 miles of Departure. Required her Course, and Latitude in.



Here Dist. : Radius : : Dep. : Sin. Course
And Rad. : Dist. : : Sin. Co-course : Diff. Lat.

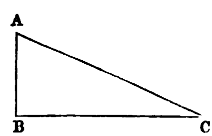
A	220 = B C	272 = A B	350 = A C
SIN	39° = A	51° = C	90°

Then 54° + 4° 32′ = 58° 32′ N. the Latitude in; and Course N. 39° E.

Ex. 5.—A ship from Lat. 56° 30′ N. sails between South and East 257 miles, till she arrives in Lat. 54° 47′ (or 103 miles of Southing). Required her Course, and Departure made good.

Here Dist. : Rad. : : Diff. Lat. : Sin. Co-course
And Rad. : Dist. : : Sin. Co-course : Dep.

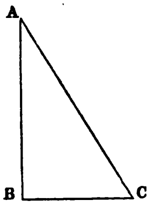
A	103 = A B	235 = B C	257 = A C
SIN	23° 38′ = C	66° 22′ = A	90°



The Course is therefore S. 66° 22′ E. and Departure 235 miles.

N.B.—Using Nat. Sines (col. 4 Table page 11) 103 ÷ 257 = ·401 = Sine of Co-course C.

Ex. 6.—A ship sailed in 24 hours, 164 miles of Southing, and 134 of Easting. Required her Course and Distance.



First find, by (*b*), page 10, the smaller angle, which since the *Diff. Lat. is greatest,* is the Course; and then find the Hyp. or Distance by (*a*), page 10.

First. AB : Tan 45° :: BC : Tan A

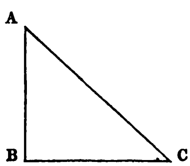
TAN	39° 15′ = Course	45°
A	134 = BC	164 = AB

Second. Sin. A : B C :: Radius : A C.

A	134 = BC	212 = Dist.
SIN	39° 15′ = A	90°

The Course therefore is S. 39¼ E. and the Distance 212 miles.

Ex. 7.—A ship sailing in the S.W. quadrant, has made in two days, 265 miles Diff. Lat. and 390 miles Departure. Required her Course, and Distance.



First find by (*b*), page 10, the smaller angle, which as the *Departure is the greatest,* is the Co-course. Secondly, find the Hyp. or Distance from the Co-course and Diff. Lat. by (*a*), p. 10.

First. BC : Radius :: AB : Tan. C (whence A is known).

TAN	34° 15′ = C or Co-course	45°
A	265 = AB	390 = BC

Second. Sin. C : AB :: Radius : A C

A	265 = AB	471 = AC
SIN	34° 15′ = C	90°

Then since C the Co-course = 34¼, A the Course = S. 55¾° W.; and Distance 471 miles.

N.B. 1st.—If the Instrument has the extra line of Tangents, it may be better in all cases, where only the 2 legs are given, to assume Diff. Lat. whether greater or shorter than Departure, as Radius; in which case when it is the shorter, we get the Course, instead of the Co-course, at the first operation. In *this* case the back of the slide must be used for the 1st, and the front for the 2d operation, as follows:

First.	TAN	45°	*Course*
	A	Diff. Lat.	Departure

Second.	A	Departure	*Distance*
	SIN	Course	90°

Thus in Ex. 7,

1st.	TAN	45°	50° 45′ = Course
	A	265	390 = Dep.

2d.	A	390 = Dep.	471 = Dist.
	SIN	55° 45′ = Course	900

N.B. 2d.—In using the line of TAN. in such Examples as 6 and 7, the Tangential angle, when less than 5° 33′ (half a Point is 5° 37½′) cannot be found, if one Leg is less than 10, without shifting the Slide. Thus if the Diff. Lat. is 103 and the Departure 9, when we place 103 on A under 45° on TAN. we cannot read what is over 9 on A. We therefore look for two coinciding figures on TAN. and A, or in the above instance, 29° over 5·8, and then shift the Slide to the right, till we get 29° over the 5·8 of the *second* Radius, when we can read 5° the answer on TAN. over 9 on A.

N.B. 3d.—When the course does not happen to fall on a whole Degree, or on a Point, ½ Point, or ¼ Point, the Slide Rule gives more correct results than the *Tables* in Navigation Books. In other cases the result is seldom in error above a mile in any day's run that a Steamer will make, or in long distances, say 1 in 300.

N.B. 4th.—If both the given Legs are of the same length, the Course will be an angle of 45°.

Footnote to page 12.

The method of solving Example 1 by "Gunter's Scale" would be described as follows, in Norie:

Extend the compasses from 8 Points (or 90°) on the line marked SIN. RHUMB. to 5 Points (the Course). That extent will measure back from 229 the Distance, on the line of NUMBERS, to 190.

Extend the compasses from 8 Points (90°) on the line S. R. to 3 Points (the complement of the Course). That extent will measure back from 229 the Distance, on the line of NUMBERS to 127. (As the Course is *large*, this 127 will be the Diff. Lat., and the 190 first found, the Departure).

It can easily be imagined that this method is longer and less accurate than that by the Slide Rule. It is difficult to measure *exactly* with the compasses, on board ship, and the lines marked on the Rule soon wear out. See also, p. 24.

TRAVERSE SAILING

is "Plane Sailing" applied to the case where a vessel from contrary winds, or other causes, makes a zig-zag track called a Traverse. Traverse Sailing is the method by which all these zig-zags are combined into *one* Course and Distance, exactly as in Examples 1, 6, and 7.

The following entry will exemplify:

Courses.	Dist.	N.	S.	E.	W.
W.S.W.	51		19·5		47·1
W. b. N.	35	6·8			34·3
S. b. E.	45		44·1	8·8	
S.W. b. W.	55		30·6		45·7
S.S.E.	41		37·9	15·7	
			132·1	24·5	127·1
			— 6·8		— 24·5
			125·3		102·6
			Southing		Westing

The Courses must be reduced to Degrees, which is done from the figures engraved on the Slide Rule which shew the Degrees and minutes corresponding to every ¼ Point.

The first two columns are what are shewn by the Log-slate. The Distance on each Course is then set on the line A, over 90° on SIN.; and the *Departure* is found over the Course, and the *Diff. Lat.* over the Co-course, as in the Formula attached to (*a*), page 10; and thus the N. S. E. W. columns are filled up, the Slide Rule superseding a "Traverse Table." Then the difference between the sum of the Northings, and the sum of the Southings, becomes a "Diff. Lat." and the difference between the sum of the Eastings, and the sum of the Westings, becomes a "Departure"; whence the *total* Course and Distance is found, as in Ex. 6, or Ex. 7.

For instance, we have first, W.S.W. or 2 Points; or 22° 30′, 51 miles; then as in Ex. 1,

A	19·5 = Diff. Lat.	47·1 = Dep.	51 = Dist.
SIN	22° 30′ = Co-course	67° 30′ = Course	90°

and so on with each of the rest. Eventually, we have a *total* Diff. Lat. = 132·1, and a *total* Departure = 102·6, whence we get the total Course and Distance, as in Ex. 6.

Firstly.	TAN	39° 19′ = Course	
	A	102·6 = Dep.	125·3 = Diff. Lat.

Secondly.	A	102·6 = Dep.	162 = Dist.
	SIN	39° 19′ = Course	90°

Or a Total of S. 39° 19′ W. 162 miles.

N.B. 1st.—Had the total *Departure* been greater than the total Diff. Lat. we should have worked as in Ex. 7.

N.B. 2d.—Since 102·6, and 125·3, are not easy places to find exactly on the Slide Rule, it would probably read a total Course of 39° 30′, with a Distance of 162 miles as before. This is quite as near as the usual "Traverse Tables" will give.

N.B. 3d.—The above are supposed to be *Compass* Courses. Had the variation been 2 Points Westerly, the total *true* Course would have been S. 16° 49′ W. and the Distance 162 miles as before. (The two legs being 155 and 47.)

PARALLEL SAILING.

THE Meridians of longitude converge to the Poles; the distance between any two, decreasing according to the Cosine of the Latitude. "Parallel Sailing" is nothing more than the reduction of miles of Longitude to nautical miles, (or else nautical miles to miles of Longitude,) according to the Latitude of the place. For instance, the Cosine of 60° is half the Radius; if then the Hour Meridians on a Globe are 1·6 inches apart, in Lat. 60° they will only be ·8 inch apart. One Degree of Longitude on the Equator is 60 Nautical miles; but in the Lat. of London 51½°, the Degree of Longitude is only 60 × ·622 or 37·3 nautical miles, or using the Formula in p. 7, this is equivalent to 43 *statute* miles; so that a person travelling 43 statute miles due West from London would have altered his Longitude by 1°, and would find his watch too fast, by 4 minutes.

This reduction of miles of Longitude to nautical miles or "Departure," is required *constantly* at sea. Remember then that Departure = Diff. Long. × Cos. Latitude, and Diff. Long. = Departure ÷ Cos. Latitude; or on the Slide Rule,

A	Departure	Diff. Longitude
SIN	Co-latitude	90°

N.B.—In using the line of SINES, when we want the *complement* of an angle, it is generally easier to *count back* the given angle from 90°, than to deduct it mentally from 90°.

Ex. 8.—A vessel in Lat. 53° 9′, ran 190·4 nautical miles due West, (or 190·4 of "Departure"). How many miles of *Longitude* is this equivalent to?

A	190·4 Departure	317·5 = Diff. Long.
SIN	36° 51′ = Co-latitude	90°

Ex. 9.—In Lat. 32° 30′, a vessel made 159′ of Longitude. What "*Departure*" in nautical miles, is this equivalent to?

A	134 = Departure	159′ = Diff. Long.
SIN	57° 30′ = Co-latitude	90°

Ex. 10.—An Indiaman off the Cape, running due East, in Lat. 39° S. made 6° of Longitude (*i.e.* found her clock 24 m. too slow) in 24 hours. How many nautical miles had she run?

A	270 = Departure	360′ = Diff. Long.
SIN	51° = Co-Lat.	90°

Ex. 11.—

Plymouth	50° 25′ N. Lat. 4° 10′ W. Long.	What number of nautical miles *go to one degree* of Longitude, at each of these places? also, what number of Statute miles?
London	51° 30′ N. Lat.	
Dublin	53° 23′ N. Lat. 6° 14′ W. Long.	
Edinburgh	55° 58′ N. Lat. 3° 12′ E. Long.	

First,

A	Departures	33·6	35·4	37·3	38·2	60′ = Diff. Long.
SIN	Co-latitudes	34° 2′ = E	36° 37′ = D	38° 30′ = L	39° 55′ = P	90°

Secondly,

A	69·1	38·7	40·8	43·0	44·0 Statute miles
B	60	33·6	35·4	37·3	38·2

or, knowing, that 60 Nautical = 69·1 Statute (p. 7), we can obtain the second set of answers as follows:

A	Statute miles	38·7	40·8	43·0	44·0	69·1′ Diff. Long.
SIN	Co-latitudes	34° 2′ = E	36° 37′ = D	38° 30′ = L	39° 55′ = P	90°

MIDDLE LATITUDE SAILING.

"Plane Sailing," in which the Easting or Westing is given in *nautical* miles, is suited to small distances, as in Bays, Channels, &c.; but out at sea, where the distances are greater, the Easting or Westing is in miles of *Longitude*. These must be reduced, as shown by "Parallel Sailing," (p. 13), to nautical miles, or "Departure," and this *one* correction made, the rest is done by "Plane Sailing." In "Parallel Sailing" the two places are supposed to be on the *same* parallel of Latitude, but, if they are not so, the *mean* of the two Latitudes* is taken as the Parallel, whence to deduce the Departure, which thus becomes = Diff. Long. × Cosine of the *middle* Latitude, or if the Diff. Long. is required, it is = Departure ÷ Cos. *mid.* Lat.

The following are the "*Proportions*," in "Middle Latitude" Sailing:—

Radius	: *Cos. Mid. Lat.*	:: *Diff. Long.*	: *Departure.*
Diff. Lat.	: *Cos. Mid. Lat.*	:: *Diff. Long.*	: *Tan. Course.*
Sin. Course	: *Diff. Long.*	:: *Cos. Mid. Lat.*	: *Distance.*

And as in "Plane Sailing,"

Diff. Lat.	: *Radius*	:: *Departure*	: *Tan. Course.*
Sin. Course	: *Departure*	:: *Radius*	: *Distance.*
Cosin. Course	: *Diff. Lat.*	:: *Radius*	: *Distance.*

N.B.—When the two Latitudes are on different sides of the Equator, there is some little difficulty in taking out the Mid. Lat. exactly; but in these cases the want of exactness is of no practical consequence. If the 2 latitudes are nearly equal, half the greater may be employed as the Middle Latitude. Thus from 29° S. to 30° N. use 15°. In intermediate cases, the two *mid* Latitudes may be combined, giving the greater weight to that which corresponds to the greater Latitude. Thus 30° N. to 14° S.; allow twice the weight to the N. Lat. and we have $\frac{(2 \times 15^\circ) + 7^\circ}{3} = 12^\circ$ nearly. If from 0° 25′ S. to 2° 37′ N. $\frac{(3 \times 1^\circ\,18') + 12'}{4} = \frac{4^\circ\,24' + 12'}{4} = 1^\circ\,8'$. If from 9° 30′ N. to 2° 44′ S. $= \frac{(4 \times 4\frac{3}{4}) + 1^\circ\,22'}{5} = \frac{19^\circ + 1'\,22''}{5}\ 4^\circ\,5'$.

---

* See the "Table," page 25, and the NOTE following it. These corrections need not be noticed, as far as any *practical* results are concerned.

	GIVEN.	REQUIRED.
I.	*One Latitude,—Course,—and Distance.*	*Diff. Lat.—and Longitude.*

Ex. 12.—A ship from Lat. 52° 6′ N. and Long. 35° 6′ W. sails N.W. b. W. 229 miles. Required her present Latitude and Longitude.*

The Diff. Lat. A B = 127, and Departure B C = 190·4, are found exactly as in Ex. 1 "Plane Sailing." This 2° 27′ of Lat. + 52° 6′, gives 54° 13′ N. the *Latitude come to;* hence the "Middle Lat." is 53° 9′; and in this Parallel, 190·4 miles of Departure = 317·5′ of Longitude, as shewn in Ex. 8. This 5° 17′ added to 35° 6′, makes 40° 23′ W. the *Longitude come to.*

N.B.—In working with logarithms, or by Nat. Sines and Tangents, we can find the Diff. Long. without first finding the Departure; for Diff. Long. $= \frac{\text{Diff. Lat.} \times \text{Tan. Course}}{\text{Sin. Co. Mid. Lat.}}$; or in the above Example 12, $\frac{127 \times 1{\cdot}5}{{\cdot}600} = 317'$ of Long.

	GIVEN.	REQUIRED.
II.	*One Latitude,—Course,—Departure.*	*Dist.—Diff. Lat.—Diff. Long.*

Ex. 13.—A ship sails S.S.W. from Lat. 51° 15′ N. and Long. 9° 50′ W. until her Departure is 250 miles. Required the Distance sailed, and her present Latitude and Longitude.†

The Diff. Lat. AB = 604, and Distance AC = 653 are found exactly as in Ex. 2 "Plane Sailing." Then the 10° 4′ of Lat. deducted from 51° 15′, gives 41° 11′ N. the *Lat. come to;* and 46° 13′, the Middle Latitude. In this Parallel (as in Ex. 8) 250 miles of Departure = 361′ of Long. This 6° 1′ added to 9° 50′, gives 15° 51′ W. the *Longitude come to.*

---

* Nearly all these Middle Latitude examples, are taken from "Norie's Epitome." The "Gunter's Scale" solutions that Norie and other works give, is quite obsolete; but they may be compared with the Slide Rule work, to shew the advantage of the latter. See pages 16 and 24.

† This, and Problem IV. are not likely to occur at sea; for except when steering *due* East or West, the Diff. Long. is more likely to be known than the Departure.

	GIVEN.	REQUIRED.
III.	*Both Latitudes,—and Course.*	*Departure,—Dist.—Diff. Long.*

Ex. 14.—A ship from Lat. 42° 25′ N. and Long. 15° 6′ W. sails N.E. b. E. and on the second day finds by observation that she is in Lat. 46° 20′ N. Required the Distance she has sailed, and her present Longitude.

Here we have given, the Diff. Lat. = 3° 55′, and the Middle Lat. = 44° 22′. Hence the *Distance* AC = 423 is found as in Ex. 3 "Plane Sailing"; as also the Departure BC = 352 miles, which in Mid. Lat. 44° 22′, are reduced to miles of Longitude (as in Ex. 8) as follows:

$$\frac{\text{A} \quad 352 = \text{Departure}}{\text{SIN} \quad 45^\circ\ 38' = \text{Co-mid. Lat.}} \qquad \frac{492' = \text{Diff. Long.}}{90^\circ}$$

This 8° 12′ deducted from 15° 6′, gives 6° 54′ W. the *Longitude come to.* If the Course is a *four* point one, the Distance = Diff. Lat. × 1·414. Or, Distance always = Diff. Lat. ÷ Sin. Co-course.

	GIVEN.	REQUIRED.
IV.	*One Lat.—Dist.—Departure.*	*Course,—Diff. Lat.—Diff. Long.*

Ex. 15.—A ship from Lat. 54° N. and Long. 33° 20′ W. sails 350 miles between N. and E. until she has made 220 miles of Departure.* Required her Course, and her present Latitude and Longitude.

By "Plane Sailing" Ex. 4, we find the *Course* A = N. 39° E. and the Diff. Lat. AB = 272 miles, which gives 54° + 4° 32′ = 58° 32′ N. *the Latitude come to;* and 56° 16′ the Middle Lat. In this parallel, (as in Ex. 8), 220 miles of Departure = 396′ of Longitude, which gives 33° 20′ — 6° 36′ = 26° 44′ W. *the Longitude come to.*

	GIVEN.	REQUIRED.
V.	*Both Latitudes,—and Distance.*	*Course,—and Diff. Long.*

Ex. 16.—Suppose a ship from Lat. 56° 30′ N. has sailed in the S.E. quadrant 257 miles, till she arrived in Lat. 54° 47′ N. Required her Course, and Difference of Longitude.

---

* See footnote to Problem II.

By "Plane Sailing" Ex. 5, we find the *Course* A = S. 66° 22′ E. and the Departure BC = 235 miles; which since the Middle Latitude is known from the data given, to be 55° 38′, is converted to miles of Longitude as in Ex. 8 as follows:

A	235 = Departure	417′ = Diff. Long.
SIN	34° 22′ = Co-mid. Lat.	90°

	GIVEN.	REQUIRED.
VI. (*a*)	*Both Latitudes—Both Longitudes.*	*Course,—and Distance.*

Ex. 17.	Place of Ship,	April 22, 31° 8′ S. Lat.	29° 50′ W. Long.	Required Course & Dist.
		April 23, 33° 52′ S. Lat.	27° 11′ W. Long.	

The Diff. Lat. being 164 miles, the Middle Lat. is 32° 30′; and (as in Ex. 9) in the parallel, the 2° 39′ Diff. Long. is reduced to 134 of Departure,* as follows:—

A	134 = Departure	159′ = Diff. Long.
SIN	57° 30′ = Co-mid. Lat.	90°

We then proceed by "Plane Sailing," as in Ex. 6, where, of the two given legs, the Diff. Lat. is greatest, and obtain the *Course* = S. 39¼° E. *Distance* 212 miles.

	GIVEN.	REQUIRED.
VI. (*b*)	*Both Latitudes—Both Longitudes.*	*Course,—and Distance.*

Ex. 18.	Cape St. Vincent	37° 3′ N. Lat.	9° 1′ W. Long.	Required Course & Dist.
	Funchal	23° 38′ N. Lat.	16° 56′ W. Long.	

The Diff. Lat. is 265 miles, and Mid. Lat. = 34° 50′. In this parallel, (as in Ex. 9) the 7° 55′ Diff. Long. is reduced to 390 miles Departure, as follows.*

---

* In working by logarithms, or Nat. Sines and Tangents, we can find the Course, without first finding the Departure; for Tan. Course $= \dfrac{\text{Diff. Long.} \times \text{Sin. Co-mid. Lat.}}{\text{Diff. Lat.}}$. So in Ex. 17 $\dfrac{159 \times {\cdot}843}{164} = {\cdot}817$ which is the Nat. Tan. of 39° 15′. Dep. ÷ Diff. Lat. also gives Tan. Course. See N.B. page 21.

A	390 = Departure	475′ = Diff. Long.
SIN	55° 10′ = Co-mid. Lat.	90

We then proceed by "Plane Sailing," as in Ex. 7, where of the two given Legs, the Departure is the greatest, and obtain the *Course* S. 55¾° W. Distance 471 miles.

N.B.—If we prefer to use the Diff. Lat. as radius, even when Departure is the greatest, (as explained in N.B. 1st, page 15,) we get the Course instead of the Co-course, in the first part of the operation.

Gunter's Scale.

To show the working on "Gunter's Scale," the method as given in Norie, for Ex. 18, is as follows:—

Extend the compasses from 90° to 55° 10′ (which is the complement of the Mid. Lat.) on the line SIN. That extent will reach on the line of NUMBERS, from 475 (the diff. Long.) to 390, the *Departure.*

Extend from 265 (diff. Lat.) to 390 (departure) on the line of NUMBERS: that extent will reach on the line TAN. from 45° to 55° 48′ the *Course.*

Extend from 34¼° (the compl. of course) to 90° on the line SIN: that extent will reach from 265 (diff. lat) on the line of NUMBERS, to 471 the *Distance.*

This may be *tried* with a pair of compasses on the lines A TAN, and SIN of the Slide Rule, or on figure 2 of the plate. It will soon be seen that the process is inaccurate, tedious, and destructive of the instrument. But when the *Slide* Rule is used, none of these defects exist, and the answers are quicker taken out than from the "Tables" generally used.

CORRECTION IN ′ TO BE ADDED TO MEAN LATITUDE.

MID. LAT.	DIFFERENCE OF LATITUDE.																			MID. LAT.
	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	
15°	1′	2′	3′	5′	7′	9′	12′	15′	19′	23′	27′	31′	35′	40′	46′	52′	58′	65′	72′	15°
16	1	2	3	4	6	9	10	15	18	21	25	29	33	38	45	50	56	62	69	16
17	1	2	3	4	6	8	10	14	17	20	24	28	32	37	43	48	54	60	66	17
18	1	1	3	4	6	8	10	13	16	19	23	27	31	36	41	46	52	58	64	18
19	1	1	3	4	6	7	10	13	18	18	22	26	30	35	39	44	50	56	62	19
20	1	1	3	4	6	7	9	12	15	18	22	25	29	34	38	43	48	54	60	20
21	1	1	2	4	5	7	9	12	15	18	21	25	29	33	37	42	47	52	58	21
22	1	1	2	4	5	7	9	12	14	17	21	24	28	32	36	41	46	51	56	22
23	1	1	2	3	5	7	9	11	14	17	20	23	27	31	35	40	45	50	55	23
24	1	1	2	3	5	7	9	11	14	17	20	23	27	31	35	39	44	49	54	24
25	1	1	2	3	5	7	9	11	13	16	19	23	27	31	35	39	43	48	53	25
26	1	1	2	3	5	6	9	11	13	16	19	23	26	30	34	38	42	47	53	26
27	1	1	2	3	5	6	9	11	13	15	18	22	25	29	33	37	42	47	52	27
28	1	1	2	3	5	6	9	11	13	15	18	21	25	29	33	37	41	46	51	28
29	1	1	2	3	5	6	9	11	13	15	18	21	25	29	32	36	41	46	50	29
30	1	1	2	3	5	6	9	11	13	15	18	21	24	28	32	36	40	45	50	30
31	1	1	2	3	5	6	9	11	13	15	18	21	24	28	32	36	40	45	50	31
32	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	45	50	32
33	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	45	50	33
34	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	44	49	34
35	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	44	49	35
36	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	45	49	36
37	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	45	49	37
38	1	1	2	3	4	6	9	11	12	15	18	21	24	28	32	36	40	45	50	38
39	1	1	2	3	4	6	9	11	12	15	18	21	24	29	32	36	40	45	50	39
40	1	1	2	3	4	6	9	11	13	16	18	21	25	29	33	37	41	45	50	40
41	1	1	2	3	4	6	9	10	13	16	18	21	25	29	33	37	41	46	51	41
42	1	1	2	3	4	6	9	10	13	16	18	21	25	29	33	37	41	46	52	42
43	1	1	2	3	5	6	8	10	13	16	19	22	26	30	34	38	41	46	53	43
44	1	1	2	3	5	6	8	11	13	16	19	22	26	30	34	38	42	47	53	44
45	1	1	2	3	5	6	8	11	13	16	19	22	26	30	34	38	43	48	53	45
46	1	1	2	3	5	6	8	11	13	16	19	22	26	30	34	39	44	49	54	46
47	1	1	2	3	5	6	9	11	13	16	19	23	26	30	35	40	45	50	55	47
48	1	1	2	4	5	7	9	11	13	16	19	23	26	30	35	40	45	50	55	48
49	1	1	2	4	5	7	9	11	13	16	20	23	27	31	36	41	46	51	56	49
50	1	1	2	4	5	7	9	11	14	17	20	24	28	32	36	41	46	51	57	50
51	1	1	2	4	5	7	9	11	14	17	20	24	29	32	36	41	47	52	58	51
52	1	1	2	4	5	7	9	11	14	18	21	25	30	33	36	42	48	53	59	52
53	1	1	2	4	5	7	9	12	15	18	21	25	30	33	37	43	49	54	60	53
54	1	1	2	4	6	8	10	13	15	18	22	26	30	34	38	44	50	56	62	54
55	1	1	3	4	6	8	10	13	16	18	22	26	31	35	39	45	51	57	63	55
56	1	1	3	4	6	8	10	13	16	18	23	27	31	36	40	46	52	58	65	56
57	1	1	3	4	6	8	10	13	17	19	23	27	32	37	41	47	53	59	67	57
58	1	1	3	4	6	8	11	14	17	20	24	28	33	38	43	48	54	61	68	58
59	1	2	3	4	6	9	11	14	17	20	24	29	34	39	45	50	56	63	70	59
60	1	2	3	4	6	9	11	14	18	21	25	30	35	40	46	52	58	65	72	60
	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	

The above Table is computed from the Formula

"Cos. *true* Mid. Lat. = Proper diff. Lat. ÷ Mer. diff. Lat."

The Meridional diff. Lat. is described under "MERCATOR'S SAILING," p. 28; and the Formula given above, is thus derived:

By Mid. Lat. Sailing (p. 20) Tan. Course $= \frac{\text{Cos. Mid. Lat.}}{\text{Diff. Lat.}} \times \text{Diff. Long.}$

By Mercator's Sailing (p. 29) Tan. Course $= \frac{\text{Radius}}{\text{Mer. diff. Lat.}} \times \text{Diff. Long.}$

whence $\frac{\text{Cos. Mid. Lat.}}{\text{Diff. Lat.}} = \frac{\text{Radius}}{\text{Mer. diff. Lat.}}$

or Cos. Mid. Lat. $= \frac{\text{Radius}}{\text{Mer. diff. Lat.}} \times \text{Diff. Lat.} = \frac{\text{Diff. Lat.}}{\text{Mer. diff. Lat.}}$

N.B.—In computing the preceding Table, Meridional Parts to *decimals* have been used. In most Navigation books, these parts are not given to decimals, and have a certain amount of error. For example, Norie in his Examples of Mercator's Sailing, asks the Course and Distance from the Cape of Good Hope in Lat. 34° 22′ S.; Long. 18° 24′ E. to St. Helena in Lat. 15° 55′ S. Long. 5° 45′ W. He makes it by Mercator's Sailing N. 49° 40′ W. 1710 miles; and adds in a note, that with the *corrected* Middle Latitude 25° 50′, the answer would be the same by Mid. Lat. Sailing. This makes his "correction" = 25° 50′ *minus* 25° 8′ 30′ (which last is the Mid. Lat. in the ordinary way) = 41° 30′; whereas by the Table in page 25, for Mid. Lat. 25° 8½′, and Diff. Lat. 18° 27′, the correction would be about 45′, instead of 41½′. The larger amount is correct, for that assumed by Norie is calculated from Tables of Meridional Parts, *not* to decimal places, and therefore agrees with his Mercator's Sailing results which are derived from the same Tables, giving 2198 — 968 = Mer. Diff. Lat. 1230. The Tables to decimals give 2198·07 — 967·52 = Mer. Diff. Lat. 1230·55; the odd ½ mile causing 3½′ difference in the "corrected" Middle Latitude. The *Distance* between the two places is not sensibly affected. By ordinary Mid. Lat. Sailing, it is N. 49° 50′ 17″ W. 1716·4 miles; by common Mercator N. 49° 40′ 24″ W. 1710·6 miles; by *True* Mercator, and corrected Mid. Lat. it is N. 49° 39′ 39″ W. 1710·1 miles. See Case 2 in the list, page 27.

In the following List, the Difference of Latitude, and the Difference of Longitude are given, and the *correct* Course and Distance of the

3d and 4th columns worked out logarithmically by "Mercator's Sailing," with the Meridional parts to decimals. The Course and Distance in the columns 6 and 7, is worked out logarithmically by "Middle Latitude Sailing," *without* the correction in page 25. The "Middle Latitude" in col. 5, is the uncorrected mean of the two latitudes, to which the correction in col. 8 is to be added, and the results in cols. 3 and 4 will be obtained.

It will be seen that the "ordinary" Mid. Lat. is too small, consequently the Departure is too great, and its opposite angle, or Course, too great; which makes the Distance too great.

		MERCATOR.		MIDDLE LATITUDE.			
Diff. Lat.	Diff. Long.	Course.	Dist	Usual Mid. Lat.	Course.	Dist.	Correction.
		° ′		° ′	° ′		′
898	1319	55 39¾	1592	4 5	55 41	1593	41¾
1107	1449	49 39½	1710·1	25 8½	49 50	1716·4	45
858	786	33 7	1024·4	44 9	33 19¼	1026·8	26¾
745	1295	51 10¾	1188·5	44 0½	51 20¾	1192·8	20
644	1237	54 24	1106·3	43 6	54 30½	1109·3	17
480	965·5	45 00	678·8	60 0	45 9¼	680·8	12
282	428	40 27	370·6	55 46	40 29½	370·8	3½
204	155	34 0¼	246·1	27 22	34 0¾	246·2	1½
240	1067	69 2½	671·0	54 0	69 3½	671·5	2
60	474	78 44¾	307·4	50 30	Same as Mercator.		0

In the 1st Example, the Latitudes are 9° 30′ N. and 2° 44′ S.; and the Mid. Lat. is found to be nearly 4° 5′, as in page 20. Though this is nearly 47′ in error, no appreciable difference in the Course and Distance results, because the Mid. Lat. is so near the Equator.

The *Latitudes* of each Example are easily found, if required, from col. 5. Thus in the 3d case, half of 858′ added to 44° 9′ gives 51° 18′ one Latitude; and half of 858′ subtracted from 44° 9′ gives 37° 0′ the other Latitude.

MERCATOR'S SAILING.

In "Mercator's Sailing," a Table of "meridional parts," (see N.B. page 30) is indispensable, and it is therefore not so well adapted to the Slide Rule, as "Middle Latitude Sailing," which when the Slide Rule is used, requires no Table *at all*. Again, though Mercator's Sailing is theoretically correct, yet it is not more so than Middle Latitude Sailing *when the correction in the Table* (page 25) is applied. Even *without* this correction, the error is not one which can possibly affect a ship, as will be seen from the List in page 27. However, as Mercator's Sailing forms part of a course of instruction in Navigation, it may be as well to explain it.

In "Middle Latitude" sailing, the error of "Plane" sailing, arising from considering the Meridians parallel, is compensated by *decreasing the Longitudes* (into Departures); whilst in "Mercator's" Sailing, it is compensated by *increasing the Latitudes* in a certain proportion; and Charts can be constructed on this principle. The coasts, islands, &c. in high latitudes, are exaggerated, but the *bearings* between any two places are correct, and the *distances* can be measured correctly from a scale. Hence, when any large surface of the earth has to be represented on a Map, Mercator's charts are employed.

The following is the proportion in which the latitudes are increased: suppose 1′ (or 1 mile) on the Equator to be a radius, the length of the first minute of latitude will be the *secant* of 1′ to that radius; the second minute of latitude will be the secant of 2′; and the third minute of latitude will be the secant of 3′; and so on for each separate minute of Latitude. Consequently, the distance from the Equator to any parallel of latitude, is equal to the *sum* of the secants of the intermediate minutes. Hence, the parallel of 10°, for instance, is made 603 instead of 600 miles from the Equator; and that of 20°, is made 1225 miles, instead of 1200. These lengths are called "Meridional Parts," and are given in works on Navigation to every minute of latitude. The difference between the Meridional Parts appertaining to any two latitudes, is the "Meridional Difference of Latitude." Thus the "Mer. Diff. Lat." between 10° and 20°, is 1225 *minus* 603 = 622 miles; between

59° 30′ and 60° 30′ it is 4588 *minus* 4468 = 120 miles; or just double the length of one degree on the Equator.

Proportions in Mercator's Sailing:—

Mer. diff. Lat. : *Diff. Long.* :: *Radius* : *Tan Course*
Mer. diff. Lat. : *Diff. Long.* :: *Diff. Lat.* : *Departure.*

The *Distance*, and *Diff. Lat.* are found as in Plane Sailing (p. 10). The *Departure* may also be found by Plane Sailing, when the Course and Distance, or Course and Diff. Lat. are known.

The Slide Rule may be employed *after* the "Mer. diff. Lat" has been obtained from the Table of Meridional Parts; and in fact it will be more correct than the subsequent Tables generally used, unless the Course happens to be *exactly* one which fits the Tables (See N.B. 3d, page 15).

Example. Required (as in No. 5 of the List in page 27,) the Course and Distance from Ushant to St. Michael's.

Ushant	48° 28′ N. Lat.	5° 3′ W. Long.	Diff. Lat. = 644 miles.
St. Michael's	37° 44′ N. Lat.	25° 39′ W. Long.	Diff. Long. 1237′.
			Mid. Lat. 43° 6′.

48° 28′ Mer. Parts = 3334
37° 44′ Mer. Parts = 2448

886 = Meridional difference of Latitude.

First. Mer. diff. Lat. : Radius :: Diff. Long. : Tan. Course.

TAN	45°	54° 24′ Course.
A	886 = M. D. L.	1237 = Diff. Long.

Secondly. (Plane Sailing). Sin. Co-course : Diff. Lat. :: Radius : Distance.

A	644 = Diff. Lat.	1106 = Dist.
SIN	35° 37′ = Co-course	90°

The Slide Rule would probably give S. 54½° W. 1110 miles; and the same by "Middle Latitude" Sailing, *with, or without*, the correction of 17′ from page 25.

No other Example need be given; but *it is to be observed* that where the Course is above 6 points, and the usual Traverse Tables

are used, "Middle Latitude" Sailing is to be preferred; for the Course may not be exactly one for which the ordinary Tables are computed.

The following case occurred at sea, Dec. 22, 1847:—

Ship's place	30° 50′ S. Lat.	17° 24′ W. Long.
Cape of Good Hope	34° 22′ S. Lat.	18° 29′ E. Long.

The Course and Distance being required, the following answers were given:—

1. By "Mercator" and Tables.... S. 83° E. 1740 miles.
2. By "Mid. Lat." and Tables .... S. 83° E. 1780 miles.
3. By Mid. Lat. uncorrected, and Slide Rule .... S. 83° 20′ E. 1830 miles.
4. True, by Logarithms, and Tables to decimal parts .... S. 83° 19½′ E. 1824 miles.

N.B.—The "Meridional Parts" for any Latitude may be found by the following Rule, where Logarithmic Tables are at hand. Let t = log. tan. of (45° + ½ Lat.). Then (log. t + constant log. 3·8984895) — 10·0 = Log. of the Meridional Parts for that Latitude.

Given Latitude 50°. Then t = 70°, whose log. tan. is 0·4389341.

$$\begin{array}{rr} \text{Log. of } 0{\cdot}4389341 = & 9{\cdot}6423994 \\ \text{Const. log.} = & 3{\cdot}8984895 \\ \hline & 13{\cdot}5408889 \\ - & 10{\cdot}0000000 \\ \hline & 3{\cdot}5408889 \end{array} = 3474{\cdot}47 = \text{"Meridional Parts" for } 50°.$$

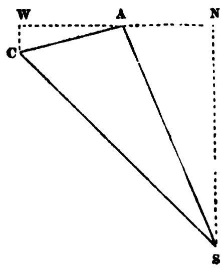
Again: required the "Meridional Parts" for Latitude 15° 55′. Here t = 7° 57½′ + 45° = 52° 57½′, whose Log. Tangent is 0·1222286.

$$\begin{array}{rr} \text{Log. of } 0{\cdot}1222286 = & 9{\cdot}0871730 \\ \text{Const. Log.} = & 3{\cdot}8984895 \\ \hline & 12{\cdot}9856625 \\ - & 10{\cdot}0000000 \\ \hline & 2{\cdot}9856625 \end{array} = 967{\cdot}53$$

CURRENT SAILING.

Apparent Course and Distance given, and also the Current; to find the true Course and Distance made good.

Ex. 19.—If a ship sail N.N.W. 60 miles, in a current setting W. by S. 25 miles in the same time, what will be the Course and Distance made good?



In the figure, we have the two sides SA = 60, and AC = 25, given, and also the included angle SAC = 9 Points; but instead of the solution as an "oblique triangle," * it is more simple to consider each side SA and AC as an Hypothenuse of a right-angled triangle,—obtain the Diff. Lat. and Departure of each, and combine them as in Traverse Sailing, p. 16. So in the above figure, SA the apparent Course is resolved into SN its Northing, and NA its Westing. The Current AC is resolved into AW its Westing, and WC its Southing. The similars are *added*, and the dissimilars subtracted, and from this combination, the Course and Distance made good are found as in Traverse Sailing, p. 16.

		N.	S.	E.	W.
N.N.W.	60 =	55·4			23
W. b. S.	25 =		4·9		24·5
		55·4			47·5 Westing
		—4·9			
		50·5 Northing.			

To find the Course,

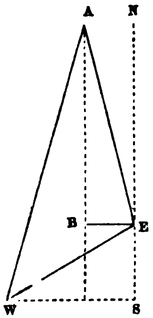
TAN	43¼ = Course N S C	45°
A	47·5 = Departure	50·5 = Diff. Lat.

To find the Distance,

A	47·5 = Departure	69·5 = Distance S C
SIN	43¼ = Course	90°

* In the separate volume of "Trigonometry by the Slide Rule," the method of solving oblique-angled triangles is given.

Apparent Course and Distance, and true Course and Distance given; to find the Set and Drift.



Ex. 20.—A ship A by her reckoning, has sailed S. b. E. 42 miles; but by observation, finds she has made a S. b. W. Course 58 miles. Required the Current.

In the figure, we have the 2 sides AE, AW, = 42 and 58, and the included angle at A = 2 Points given; but instead of the solution as an "oblique-"angled triangle,* it is simpler to work it as a *reversed* Traverse; *i.e.* when the two sides have been resolved into Southings, Westings, &c. similars are *subtracted*, and dissimilars added. Thus in the right-angled triangle ESW of the figure, the *difference* ES between the supposed and true Southings, is one Leg, and the *sum* SW of the supposed Easting and true Westing, is the other Leg; whence the Course or set of the current is SEW, and the Distance or drift is EW; as in page 17.

		N.	S.	E.	W.
S. b. E.	$11\frac{1}{4}°$ 42		41·2	8·2	
S. b. W.	$11\frac{1}{4}°$ 58		56·9		11·3
			15·7		11·3
					8·2
					19·5

To find the Course or Set,†

TAN	39° = Co-course	45°
A	15·7 = Diff. Lat.	19·5 = Dep.

To find the Distance or Drift,

A	15·7 = Diff. Lat.	25° = Dist.
SIN	39° = Co-course	90°

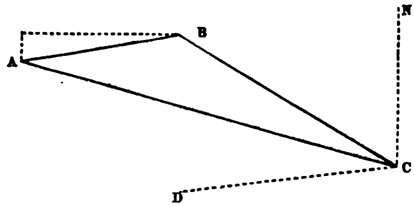
* See footnote, p. 31.

† Or with the *extra line of Tangents*, (N.B. p. 15),

TAN	45°	51° = Course
A	15·7	19·5

True Course, and rate of sailing, with Current and its rate given; to find the "apparent" Course, or Course to be steered.

The bearing of A, the port to which a vessel at C is bound, is W.N.W. but the tide is setting W. ½ S. 4 miles an hour, in the direction C D. What course must the vessel steer, if her rate is 8 knots an hour?



Here we have given the angle BAC = ∠ ACD, or 2½ Points; and the side BC = 8 miles. Then by the Rule which applies both to Right-angled and Oblique triangles, viz. that the sides are in proportion to the Sines of the angles opposite them, we have BC : Sin. BAC :: AB : Sin. BCA; and BCA deducted from NCA (a W.N.W. bearing), leaves NCB the Course to be steered.

To find ∠ BCA,

A	4 = AB	8 = BC
SIN	13° 39′ = BCA	28° 7′ = BAC

Then 67° 30′ (or W.N.W.) *minus* 13° 39′ = N. 53° 51′ W. the Course to be steered.

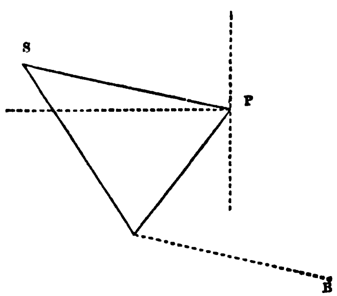
N.B.—The more complicated cases, which seldom occur, are better solved by a Diagram, with protractor and Plane Scale.

WINDWARD SAILING

Is the resolution of an Oblique-angled triangle, in which one side, and all three angles are given ; and it is required to find the other two sides.

N.B.—It will save trouble to remember that the angle made by tacking (which in the diagrams will be lettered S) is always, whatever the length of the boards made, equal to the complement of the sums of the angles made between the ship's course and the wind, on the two tacks. Thus if a vessel makes good a 6 Point course on both tacks, the sum is 12 Points, and the complement of this, 4 Points or 45° is the angle made in tacking, or S. So if the vessel makes 6 Points good on one tack and $5\frac{1}{2}$ on the other, the angle S is equal to $16 - 11\frac{1}{2}$ Points, or 5 Points, or $56\frac{1}{4}$°. (The angles corresponding to every Quarter Point are engraved on the Slide Rule.) Hence one angle S, or that opposite the side joining the ship's place at starting, and the Port, is always known ; as also the angle denoting the Points from the wind ; whence the 3d angle is known. The " Proportion " is *Sin. of any angle* : *opposite side* :: *Sin. of another angle* : *its opposite side*. Or,

$$\frac{\text{A} \quad \text{Given distance}}{\text{SIN} \quad \text{Angle S}} \qquad \frac{\text{Distance sailed on that tack}}{\text{Angle opposite any board}}$$



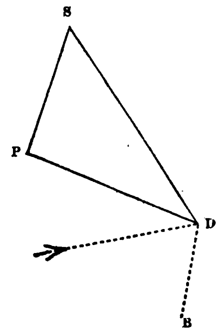
Ex. 21.—A ship at D is bound to a Port P, 26 miles dead to windward, the wind being N.E. ; and it is intended to fetch the Port in two boards, the first being on the starboard tack. The ship can make good a 6 Point course on each tack ; *i.e.* she could lay up either DS. or DB.

Here S = complement of 12 Points ; *i.e.* 4 Points, or 45°.

Required the number of miles she must sail on the starboard tack DS. (The same of course on the other tack.)

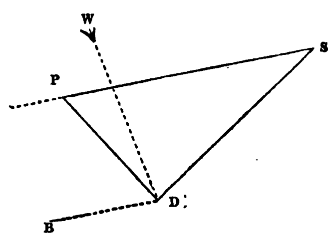
A	26 = DP	34 = DS
SIN	45° = $\angle$ S	67° 30′ = $\angle$ P

N.B.—It will easily be seen that $\angle$ SPD = PDB which is 6 Points, or 67° 50′; or since SD and SP are equal, the angles P and D are each equal $\frac{180° - S}{2}$.



Ex. 22.—Suppose the wind at W. b. S., and P. the Port, bearing W. N. W., 20 miles. The Ship at D can make good a N. W. b. N. course towards S, on the port tack, or S. b. W. towards B, on the starboard tack. How many miles must be sailed on each tack, to reach P in two boards? (It does not matter which tack is taken first, but let it be the port one.) Here S = 16 — 12 = 4 Points, and the angle SDP = 6 — 3 or 3 Points; and SPD or PDB = 9 Points or 78¾°. See page 2.

A	15·71 = SP	20 = DP	27·75 = SD
SIN	33° 45′ = $\angle$ D	45° = $\angle$ S	78° 45′ = $\angle$ P



Ex. 23.—The wind at N. N. W., and the ship at D, I wanted to reach in two boards, the mouth of a river at P, which bore N. W. ½N. 10 miles. The ship laid 5½ points from the wind, with ½ a point leeway, and an extra point leeway on the starboard tack, owing to the tide. Required the Course and Distance on each tack; (the ship can make good either WDS = 6 points, or WDB = 7 Points.)

A	10 = DP	13·9 = DS	17·9 = SP
SIN	33° 45′ = S	50° 37½′ = $\angle$ P	84° 22½′ = $\angle$ D

$\angle$ D is 8½ Points, but Sin 95° 37½′ = Sin 84° 22½′. See page 2.

It is easily seen that the angle DPS = PDB, or 6 — 1½ Points = 4½ Points.

N.B.—Whatever the number of boards a ship makes, the sum of the distances on each tack, will be equal to the sum of the two distances, had the place been fetched in two boards.

Ex. 24.—To make a degree of latitude a day, against a due N. or S. wind, the ship making good, including leeway, 6½ points, at what rate per hour must she sail? (First find the miles on each tack, as in Ex. 21.) Here $\angle$ S = 16 — 13 or 3 Points, and the $\angle$ P = 6½ Points.

A	60 = DP	103 on each tack.
SIN	33° 45′ = S	73° 7′ = P

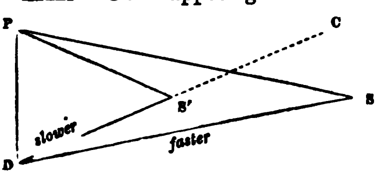
Then 206 is the whole distance sailed, and $\frac{206}{24} = 8{\cdot}6$ knots an hour.

N.B.—Since it is an isosceles triangle, and $\angle$ S the included angle, each of the other angles must be $= \frac{180° - \angle S}{2} = \angle P$.

Ex. 25.—If a ship averages 6 knots an hour, and, including leeway, makes good only a 7 Point course, how far will she work to windward in 24 hours? (This is the reverse of the preceding Example) 6 × 12 = 72 miles on each tack.

A	28 miles	72 on each tack.
SIN	22° 30′ = S	78° 45′ = P

Ex. 26.—Supposing two vessels A and B, to start together from D; A sailing 6 points, and B 7 points off the wind. How much faster must B sail than A, ever to come up with her?



In the figure, DS′P is the course of A, and DSP that of B. A puts about at S′, the moment B tacks at S, for it is evident that if she stood on towards C, she would be sooner come up to. D S′ or P S′ may be considered as the

unit, or 1·0, and what we want to know is, the proportion that DS bears to it. First we find PD, and then we get a known side opposite a known angle S, whence we get DS.

Now the angle at S', as shewn in the N.B. page 34, is equal to the complement of double the angle the ship makes with the wind, or 16 Points *minus* 12 Points, or 45°; and in the same way the angle at S is 2 Points, or 22° 30'.

First, Sin. PDS' (or 6 p.) : PS' (or 1) :: Sin. S' (or 45°) : PD.

A	·765 = PD	1 = PS'
SIN	45° = S'	67° 30' = $\angle$ PDS'

Secondly, as in Ex. 21, we find the miles in each tack DS, and SP.

A	·765 = PD	1·96 = PS
SIN	22° 30' = S	78° 45' = PDS

Therefore B must sail 1·96 times as fast as A, or 10 knots to her 5·1, and will come up to her in twice the time that it takes B to sail from D to S; but B can put about as soon as he pleases, and thus make the time indefinitely short.

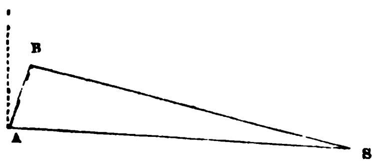
N.B.—If DS' is always considered the unit, or 1·0, the following are the values of PD for the *first* part of the operation.

Ship from the Wind.	Value of PD.	Ship from the Wind.	Value of PD.
5 Points.	1·1	6¼ Points.	·674
5¼ "	1·03	6½ "	·581
5½ "	·943	6¾ "	·486
5¾ "	·855	7 "	·390
6 "	·765		

The angle PDS is always equal $\frac{180° - S}{2}$. It is the angle from the wind that the faster vessel sails.

Ex. 27.—With the wind at N. two vessels in company are bound directly to windward, but do *not* tack. One makes a 6 point course, the other a 7 point course. The first sails 7 knots an hour. How many knots must the other sail to attain the same Northing in the same time?

Answer. The case is just the same as if they were chasing and *did* tack. By Ex. 26, the less weatherly vessel must sail 1·96 knots to the other's 1, or 13·7 per hour.



Ex. 28.—A vessel at A, steering E. $\frac{1}{2}$ S., sights another vessel B, bearing N. N. E. 10 miles off, steering 1 point higher, or E. b. S. $\frac{1}{2}$ S. They meet at S. Which has been sailing the fastest?

Here $\angle$ A $= 6\frac{1}{2}$ p. $\angle$ B $8\frac{3}{4}$ p. whence $\angle$ S $=$ 1 point, or 11° 15′.

A	10	BS = 49	51 = AS
SIN	11° 15′	67° 30′ = A	84° 23′ = B

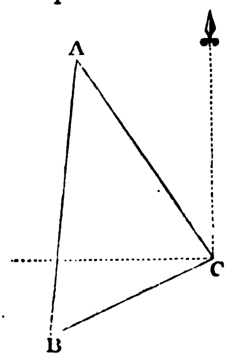
whence the vessel at A has been sailing the fastest.

N.B.—Here, instead of using 95° 37′ for the angle at B, we use its *supplement* 84° 23′. (See p. 2.)

TAKING DEPARTURES BY CROSS BEARINGS.

These cases are generally solved more easily by "construction," than by calculation with Logarithms; but the Slide Rule has advantages over "construction;" for a simple sketch, not necessarily drawn to scale, is all that is required; and it gives results as near, for all practical purposes, as Logarithms; and very much quicker, and no "Tables" required.

N.B.—When two bearings of a place are taken from two different stations, the angle at the place observed, is the difference between the two *reversed* compass bearings, as shown in the following Example:

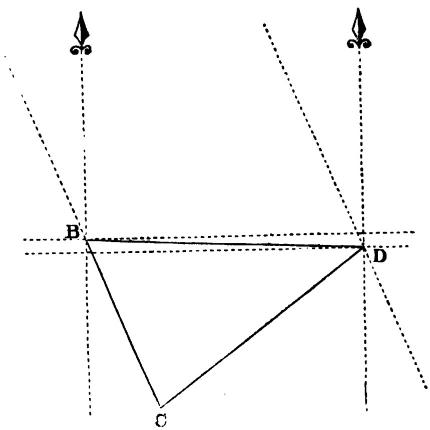


Ex. 29.—Sailing down Channel at C, I observed the Eddystone at A, bearing N. W. b. N.; and continuing a W. S. W. course, I observed when at B, after running 18 miles, that it bore N. b. E. Required its distance from C, and from A. Reverse the Bearings; then the difference between S. E. b. S. and S. b. W. is 4 Points, or 45° for the angle A, opposite the given side BC $=$ 18. It is also evident that the angle ACB is $5 + 2$ or 7 Points; whence B $=$ 5 Points. Then by the "proportion" in p. 34,

A	18 = CB	21·2 = AC	25 = AB
SIN	45° = ∠ A	56° 15′ = ∠ B	78° 45′ = ∠ C

It is not at all necessary to draw the diagrams to scale, but some rough sketch should always be made.

Ex. 30. — Being close in with Dungeness at D, I sailed 27 miles in the S. W. quadrant, as far as C, and then found Beachy Head bear by compass N. N. W. Now Beachy Head bears by compass from Dungeness W. ¼ N. 29 miles. Required the *distance* from the last station C, to Beachy Head, and the *course* (by compass) made good.



Reverse the Bearings; then the difference between E. ¼ S., and S. S. E. is 5¾ Points, = angle B; and we have the 2 sides DB and DC given as 29 and 27. First we find the angle C, *and without moving the Slide*, take out BC opposite the angle D. (The angles corresponding to the Points are engraved on the Rule.)

A	18·8 = BC = *Dist.*	27 = DC	29 = DB
SIN	39° 10′ = ∠ D	64° 21′ = B	76° 9′ = ∠ C

After angle C is found, angle D is of course 180° — (C + B).

Now the bearing of B from D, is W. 2° 49′ N., and this subtracted from D, gives the angle ADC = 36° 21′; the *complement* of which, or the angle from the *meridian*, is the Course S. 53° 39′ W.

N.B.—If the course thus *made*, differs from that steered by compass, the difference is owing to a Current, or to "local attraction;" but not to "variation," unless the *true* bearings had been worked throughout.

Ex. 31.—The ship's course was N. 60 E. Passing a lighthouse at 1 P.M. it bore N. 15° W. and at 4 P.M. N. 50° W.; the ship having run 18 miles. Required the distance from the last Station.

Here	A	18	30·3 the answer.
	SIN	35°	75°

USEFUL FORMULÆ. (See p. 6, Appendix A.)

I.	A	1·15	23	Statute miles
	B	1	20	Nautical miles
II.	A	1	27	French "brasses"
	B	·888	24	English "fathoms"
III.	A	1		Statute miles
	B	4·7		Seconds of sound
IV.	C	1	42	Height in feet (30)
	D	1·064	6·9′	*True* Dip. in ′ (350″)
V.	C	1	33	Height in feet (40)
	D	·975	5·6′	*Apparent* Dip. in ′ (370″)
VI.	C	5		Feet above level
	D	3 [2·61]		Stat. miles [Nautical]
VII.	A	Angle in ′		Subtense in feet
	B	1145		Dist. in yards
VIII.	A	Angle in ′		Subtense in feet
	B	·651 [·566]		Dist. in Stat. miles [Nautical]
IX.	A	6 Hours	55 Minutes	Sid. to Solar Time
	B	59 Minutes	9 Seconds	

Arc into Time.

Multiply by 4. This turns degrees of Arc into minutes of Time; minutes into seconds; and seconds into 60ths

Example:

$$\begin{array}{r} 80^{\circ}\ \ 14'\ \ 19{\cdot}5'' \\ 4 \\ \hline 320\text{m. } 57\text{s. } 11\text{-}60^{\text{ths}} \\ \text{or, } 5\text{h. } 20\text{m. } 57\tfrac{1}{4}\tfrac{8}{0}\text{sec.} \end{array}$$

Time into Arc.

Reduce all to minutes and seconds; and any decimals of seconds into 60ths. Then divide by 4.

Example:

2h. 24m. 46·4s. = 144min. $46\frac{24}{60}$s.

Divide by 4 = 36° 11′ 36″

Application of the above Formulæ.

1. The report of a cannon is heard 20 seconds after the flash is seen. By Formula III. the distance is $4\frac{1}{4}$ Statute miles.

2. At the height of 127 feet above the sea, the *true* dip is, by Formula IV., 12′, and by Formula V. the *apparent* dip (which is what is used at sea) is 11′.

3. The eye being 22 feet above the sea, I can just see the light of a lighthouse, on the horizon; and this light I know to be 125 feet above the water. By Formula VI., we have 5·47 Nautical miles as the distance if the light were on the water; and 13·05 the distance of the sea horizon as seen from the light; making a total distance of 18·52 Nautical miles.

4. If a man 6 feet high, subtends an angle of 6·9′, his distance by Formula VII. is 1,000 yards; and a foot-rule at the distance of one mile will subtend ·651′, or 39″.

5. By Formula IX., if 2h. 21m. Sidereal time is given, we deduct 23 seconds, to obtain 2h. 20m. 37s. Mean Solar Time.

N.B.—To find the *true* distance from a mountain, whose height is known, and its angle observed, and its *estimated* distance given, see APPENDIX B.

SPHERICAL TRIGONOMETRY.

QUESTIONS relating to "Amplitude"—"Time of sunrise or sunset"—"Prime Vertical"—&c., which are of constant occurrence at sea, are easily and quickly solved by the Slide Rule, without requiring any *Tables*. (The figure in APPENDIX G, shows the Right-angled triangle, in which DA = Amplitude,—DN = Ascensional difference,—AN = Declination; and ADN = Colatitude.)

AMPLITUDE.

This is to find the variation of the compass. (APPENDIX E.) If the observed amplitude is to the *right* of the true, the variation is *Westerly*, and *vice versâ*.

The bearing of the sun must be taken when its lower limb is a semidiameter above the horizon. The sun's centre is then really on the horizon; but it appears higher, owing to *refraction*, which is about 32′ or a sun's breadth.

The Amplitude is reckoned *from the E. or W.* points, towards the N. or S.; towards the N. if the Declination is N., and *vice versâ*.

Formula. $\text{Sin. Ampl.} = \dfrac{\text{Sin. Decl.}}{\text{Sin. Co-lat.}}$

Ex. 32.—Required the true amplitude of the Sun's centre, in Lat. 48° 21′ N., when the Declination is 16° S.

Without moving the Trigonometrical Slide, read off the Nat. sines of 16° the Decl., and of 41° 39′ the *Co* latitude = ·276 and ·665.* Then on the Arithmetical slide $\frac{A}{B}$, solve $\frac{\cdot 276}{\cdot 665} = \cdot 415$; which ·415 is shown by line SIN. to be 24° 30′. The sun therefore rises E. 24° 30′ S., or sets W. 24° 30′ S.

* In most instances, the extra line of Sines on the *back* of the Slide, mentioned in page 3, may read nearer than the other.

Or we may use the "proportion" Sin. Co-lat. : Rad. :: Sin. Decl. : Ampl.

A	·415	1
SIN	16° = Decl.	41° 39′ = Co-lat.

and ·415 = Nat. sine of 24° 30′ as before.

If the *Compass* bearing at Sunset was W. 28° S., the *variation* is 3° 30′ Easterly.

Ex. 33.—In Lat. 26° 32′ N. and Decl. 0° 43′ S., required the Amplitude. Nat. sine 63° 28′ or Co-latitude = ·895, and of 0° 43′ = ·0125. Then with the Slide $\frac{A}{B}$, $\frac{\cdot0125}{\cdot895}$ = ·0140; which on the line SIN gives 0° 48′, or W. 0° 48′ S. the *true* amplitude.

Or, using the "proportion" Sin. Co-lat. : Rad :: Sin. Decl. : Ampl.

A	·0140	1
SIN	0° 43′	63° 28′

and ·0140 = 0° 48′ as before.

ASCENSIONAL DIFFERENCE

Is the time between 6 o'clock apparent Time (or in the case of a star, 6h. from its transit over the Meridian) and the moment of Rising or Setting. The Sun is to be observed when its lower limb is a semi-diameter above the horizon, as in the case of Amplitude, p. 42.

When Lat. and Decl. are of the *same* name, the Asc. diff. is to be added to the time of Setting, and subtracted for Rising. If of *different* names, subtract from 6h. for Setting, and add for Rising.

The time of Sunrise or Sunset thus found, is the *Apparent Time*, and requires the correction of "Equation of Time" to reduce it to *Mean* time.

Formula. Sin. Asc. diff. = Tan. Lat. × Tan. Decl.

Ex. 34.—In Lat. 31° 10′ N. and Decl. 11° 14′ S. required the Sun's Ascensional difference.

Without moving the Trigonometrical Slide, take out the Nat. Tangents of 31° 10′ and 11° 14′, = ·605 and ·199. Multiply these on the Slide $\frac{A}{B}$, and find ·1203, which on the Trigonometrical Slide is found to be the Nat. Sine of 6° 54′. Turn this into *Time* as in page 41, and obtain 27m. 36 sec. Then Lat. and Decl. being of *different* names, this amount is to be added to 6 o'clock Apparent time for Sunrise, and deducted for Sunset.

Or if we use the "proportion" Rad. : Tan. Lat. :: Tan. Decl. : Asc. diff. find the Nat. Tan. of the Latitude ·605 as before ; then

A	·605 Tan. Lat.	
SIN	6° 54′ = Asc. diff. in Arc.	
TAN		10° 14′ = Decl.
A		1

Ex. 35.—Required the Sun's Asc. diff. in Lat. 51° 31′ N. when the Declination is 20° N.

The line of TAN gives the Nat. Tangents of 51° 31′ * and 20°, = 1·26 and ·364. These multiplied on the Slide $\frac{A}{B}$ give ·458, which on line SIN is found to be the Nat. Sine of 27° 15′. This reduced to *time* as in p. 41, gives 1h. 49m. to be subtracted from 6h. for Sunrise, or added for Sunset, because Lat. and Decl. are both North.

Or using the "proportion" Rad. : Tan. Lat. :: Tan. Decl. : Asc. diff.

A		1·26 = Nat. Tan. Lat.
SIN		27° 15′ = Asc. diff. in Arc.
TAN	20° = Decl.	
1	1	

Ex. 36.—In Lat. 14° S., August 11th, required the time of the rising of *a* Centauri, whose Decl. is 60° 12′ S. ; its transit over the

* If there is no extra line of Tangents on the back of the Slide, the Nat. Tan. of 51° 30′ must be found as shewn in page 4.

Meridian* being at 5h. 4m. Apparent time, which makes its "6 hour circle" 11h. 4m. App. time. As Lat. and Decl. are of the same name, the Asc. diff. for *Rising*, is to be subtracted from this 11h. 4m.

Without moving the Trigonometrical Slide, find the Tangents of 60° 12′ † and 14° = 1·75 and ·249. Then by the Slide $\frac{A}{B}$ 1·75 × ·249 = ·435, which on the line of SIN is shewn to be the Nat. Sine of 25° 48′. This reduced to *time*, as in page 41, gives 1h. 43m. which deducted from 11h. 4m. gives 9h. 21m. P.M. as the time of rising, *i.e.* when the star seems 33′ or a Sun's breadth, above the horizon, For *Mean* time, apply the Equation.

N.B.—If the Declination of a heavenly body is greater than the Co-latitude of the place, and if δ and λ are of *different* names, it will never rise above the horizon. If the Declination of the heavenly body is greater than the Co-latitude of the place, and δ and λ of the *same* name, it will never set below the horizon.

PRIME VERTICAL.

The best time to take an altitude of a heavenly body, is when it bears due E. or due W. (*i.e.* on the Prime Vertical), unless it is very low down on the horizon, in which case the refraction is too great.

No heavenly body can come to the Prime Vertical, unless its Declination is less than the Latitude of the place, and of the *same name*. If it is on the Equinoctial, it is on the Prime Vertical at the time of its rising or setting, which in this case is 6 o'clock, Apparent time.

---

* For such purposes as this, the App. Time of transit is found near enough, by subtracting the R. A. of the Sun at App. Noon, from the R. A. of the Star *plus* 24h., if necessary.

† See footnote to previous page.

Altitude of Prime Vertical.

Formula. $\text{Sin. Alt.} = \dfrac{\text{Sin. Decl.}}{\text{Sin. Lat.}}$

Ex. 37.—In Lat. 51° 30′ N. and Decl. 23° N., required the true altitude of the Sun's centre, when on the Prime Vertical.

Without moving the Trigonometrical Slide, take out the **Nat.** Sines of 51° 30′ and 23°, viz. ·783 and ·391. Then with the Slide $\frac{A}{B}$, solve $\frac{\cdot 783}{\cdot 391} = \cdot 500$; which by referring again to the Trigonometrical Slide is found to be the Nat. Sine of 30°; *i.e.* the *true* altitude of the Sun's centre (by Logarithms 29° 57′). Its *apparent* altitude will be $1\frac{3}{4}'$ more, on account of refraction, and if the eye is 17 feet above the sea, its apparent altitude will be 4′ more, on account of Dip. See page 40, Formula V.

Using the "proportion" Sin. Lat. : Rad. :: Sin. Decl. : Sin. Alt.

A	·783 Nat. Sin. Lat.	1
SIN	23° = Decl.	30° = Alt.

Time of passing Prime Vertical.

The time is, of course, *Apparent* time.

Formula. Cos. Hour angle = Tan. Decl. × Tan. Co-lat.

Ex. 38.—In Lat. 31° 28′ S. and Decl. 14° 11′ S. when does the Sun come to the Prime Vertical, in Apparent Time?

Without moving the Trigonometrical Slide, take out (as in p. 4) the Nat. Tangents of 58° 32′ (the *Co*-lat.), and 14° 11′, viz. 1·64 and ·252. Multiply these on the Slide $\frac{A}{B}$, and obtain ·413, which the Trigonometrical Slide shews to be the Sine of 24° 23′, or *Cosine* of 65° 37′, the Hour angle in arc. Reduce this to *time* as in page 41, and find 4h. 22m. 28s. (the correct answer is 4h. 22m. 26s) which would be the *Apparent* time P.M. (or 7h. 37m. 32s. A.M.) when the Sun is on the Prime Vertical.

Or using the "proportion" Rad. : Tan. Decl. :: Tan. Co-lat. : Co-sin. H ; find the Nat. Tangent of the Co-lat. 1·26 as before; then

A		1·64 Nat. Sin. Co-lat.
SIN		24° 23′ Cos of Hour angle.
TAN	14° 11′ = Decl.	
	1	

If it is a *star,* we must apply the Hour angle to its Time of Transit. (See footnote, p. 45.)

AZIMUTH AND ALTITUDE AT VI. O'CLOCK.

The Azimuth is reckoned from the South in N. Lat.; or from the North in S. Lat. If the observed Azimuth is to the right of the true, the "variation of the compass" * is *Westerly.*

The "time" referred to is *Apparent* time; or in the case of a star, it is 6h. from the time of its meridian passage, found as in the footnote to page 45. The "altitude" is the *true* altitude of the Sun's centre.

For Azimuth. Co-tan. Az. = Sin. Co-lat. × Tan. Decl.

Ex. 39.—What is the Azimuth of the Sun's centre at 6 o'clock Apparent Time, in Lat. 51° 30′ N. and Decl. 23° 28′ N.?

Without moving the Trigonometrical Slide, take out the Nat. Sines of 38° 30′ (*Co*-lat.), and 23° 28′, viz. ·622 and ·434. Multiply these on the Slide $\frac{A}{B}$, and obtain ·270, which the Trigonometrical Slide shews to be the Tan. of 15° 8′; giving S. 74° 52′ W. as the Azim.

For Altitude. Sin. Alt. = Sin. Lat. × Sin. Decl.

Ex. 40.—Required the altitude, at the same place and time as in the previous Example.

---

* For the Azimuth at any other hour, see page 52. Refer also to Appendix E.

Without moving the Trigonometrical Slide, take out the Nat. Sines of 51° 30′, and 23° 28′ = ·783 and ·398. Their product is ·312, which is the Nat. Sine of 18° 10′, the *true* alt. of the Sun's centre. The *apparent* altitude is about $2\frac{1}{4}'$ more for Refraction, and 4′ more still, for Dip, if the eye is 17 feet above the sea.

LONGITUDE INTO RIGHT ASCENSION.

Formula. Tan. A. R. = Tan. Long. × ·9167.

(Here ·9167 = Cosine of 23° 27′ 43″ the Obliquity of the Ecliptic.)

Ex. 41.—Reduce 77° of Longitude to A. R.

Find, as in page 4, the Nat. Tan. of 77° = 4·33; and on the Slide $\frac{A}{B}$ multiply 4·33 by ·917 = 3·97; the Nat. Tan. of which (as in p. 4) is 75° 52′. This reduced to *time*, as in p. 41, gives 5h. 3m. 38s. for A. R. The *correct* A. R. is 5h. 3m. 33s.

or

TAN	45°	77
A	·917	3·97

or if there is no extra Slide

A	13° (compl. 77°)	45°
TAN	·917	3·97

Ex. 42.—Reduce 266° of Longitude to A. R.

For 266° use its difference from 180°, *i.e.* 86°, as in page 2. Then 14·3 × ·917 = 13·1 which is the Nat. Tan. of 85° 38′. Then 180° + 85° 38′ = 265° 38′, or in *time* (as in page 41) 17h. 42m. 32s. is the A. R.

TWILIGHT.

• On the general assumption, that it is not *quite dark* till the Sun is 18° below the horizon, it is Twilight all night when the Lat. *plus* the Decl. being of the same name, exceed 72°.

Twilight when shortest.

We have to find, at what *Declination* of the Sun, the twilight is shortest, and then refer to the Almanac for the day.

Formula. Sin. Decl. = Sin. Lat. × ·1583 (Nat. Tan. 9°).

Ex. 43.—In the Latitude of Madras, 13° 4′ N. when will Twilight be shortest?

A	·158	1
SIN	2° 3′ = Decl.	13° 4′

Since the Lat. is N. the Decl. will be S.; and the Sun has 2° 3′ South Declination, about March 15th and September 18th.

Hence on the Equator, the Twilight is shortest when the Sun has a Decl. of 9°, or about 13th April and 30th August.

Duration of shortest Twilight.

$$\textit{Formula.}\quad \text{Sin.}\,\frac{\text{Duration}}{2} = \frac{\cdot 1564\ (\text{Sin. } 9^\circ)}{\text{Sin. Co-lat.}}\,.$$

Ex. 44.—What is the *duration* of the shortest Twilight, at Madras, in Lat. 13° 4′ N.

Sin. 9°	A	·161 = ½ duration	1
Sin. 76° 56′	SIN	9	76° 56′ = Co-lat.

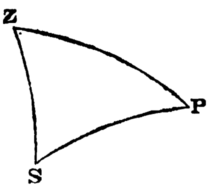
And the Line of SIN shews ·161 to be the Nat. Sin. of 9° 15′; whence 18° 30′ in arc, or (as by page 41) 1 h. 14 m. in *time*, is the answer.

Hence on the Equator, when the Sun's Declination is 9°, the arc of twilight is 18°, = 1 h. 12 m. the shortest possible Twilight anywhere.

N.B.—Though in theory, Twilight lasts till the Sun is 18° below the horizon, yet in general parlance it may be said to be dark when it is 10° below the horizon. In this case, in the above Examples, we should use ·0875 (or the Nat. Tan. of 5°) in Ex. 43; and Sin. 5° instead of Sin. 9° in Ex. 44; giving 17th March and 26th Sept. (Decl. 1° 16′ S.) for Ex. 43; and 5° 10′ = 41 m. 20 s. for Example 44.

OBLIQUE SPHERICAL TRIGONOMETRY.

TIME AND AZIMUTH.



The figure represents the kind of oblique spherical triangle, the resolution of which is most frequently required at sea. (See Appendix G.) S is the place of the heavenly body observed. ZS is its Zenith distance, and P the Hour-angle opposite. PS is the Polar distance, and Z the angle of Azimuth opposite. ZP is the co-latitude of the place where the observation is taken.

In the following Formula, A is the angle sought, and a the side opposite to it. Also h = half the sum of the three sides $a + b + c$.

$$\text{Sin. } \tfrac{1}{2} \text{ A} = \sqrt{\frac{\sin.(h-b) \times \sin.(h-c)}{\sin. b \times \sin. c}}.$$

(I.) To find the "Hour-angle," and thence the time.

Ex. 45.—In Lat. 36° 30′ N. the *true* altitude of the sun's centre was 24° 00′, and the corrected Declination 13° 50′ N. Required the Hour-angle, and thence the apparent time from Noon.

a = Zen. Dist.	66°	00′		All these are taken out from the extra line of Sines at the back of the Trigonometrical slide.
b = Pol. Dist.	76	10	Nat. Sin. ·971	
c = Co-Lat.	53	30	Nat. Sin. ·804	
2)	195	40		
h =	97	50		
$h - b$	21	40	Nat. Sin. ·369	
$h - c$	44	20	Nat. Sin. ·699	

Then $\tfrac{1}{2}$ A $= \sqrt{\dfrac{\cdot369 \times \cdot699}{\cdot971 \times \cdot804}}$; and ·971 × ·804 with Slide $\dfrac{\text{A}}{\text{B}}$ = ·780.

Then $\tfrac{1}{2}$ A $= \sqrt{\dfrac{\cdot369 \times \cdot699}{\cdot781}}$ =

A		·369
B		·781
C	·699	
D	·574 = $\tfrac{1}{2}$ A	

sin page v., Appendix A.

Then the line of SINES shews ·574 = 35° = ½ A; whence A = 70°, and this reduced to *Time*, as in p. 41, gives 4h. 40m. as the "Hour-angle," or time from Apparent noon, either A.M. or P.M.

The *exact* value of ½ A is 35° 5′ 43″, and the "Hour-angle" 4h. 40m. 46s. An error of 1′ in the angle ½ A, produces an error of 2′ of Longitude or 8 seconds of Time. The present Example was worked out ½ A = 35°, by the Slide Rule, and after a little experience it will generally give a result as near, or nearer.

Ex. 46.—In Lat. 18° 18′ N. the true altitude of Procyon, *west* of the meridian, was 23° 54′, its Decl. being 5° 34′ N. What was the "Hour-angle," or time elapsed since its transit over the meridian?

a = Zen. Dist. 66° 6′			All these are taken out from the extra line of Sines on the back of the Trigonometrical slide.
b = Pol. Dist. 84 26	Nat. Sin. ·995		
c = Co-Lat. 71 42	Nat. Sin. ·950		
2)222 14			
h = 111 7			
h — *b* 26 41	Nat. Sin. ·449		
h — *c* 39 25	Nat. Sin. ·635		

Then $\frac{1}{2} A = \sqrt{\frac{\cdot449 \times \cdot635}{\cdot995 \times \cdot950}}$. Multiply ·995 × ·950 by the slide $\frac{A}{B}$.

Then $\frac{1}{2} A = \sqrt{\frac{\cdot449 \times \cdot635}{\cdot945}} =$

A		·449
B		·945
C	·635	
D	·550 = ½ A	

Then the line of SINES shews ·550 = 33° 20′ = ½ A; whence A = 66° 40′, which reduced to *Time*, as in p. 41, gives 4h. 26m. 40s. the "Hour-angle." The above was worked by the Slide Rule alone, without any Tables. The *exact* value of ½ A is 33° 19′ 11·5″, and the "Hour-angle" 4h. 26m. 33·5s.

If in the above Example, we had given, the Star's R. A. = 7h. 32m. 4s., and the Sun's R. A. = 19° 8′ 47″, we obtain the "Apparent Time" as follows:

The H.-angle *plus* the R. A. of the Star if *west* of the meridian, or *minus* if *east*, gives the "Right ascension of the meridian" (or what

would be the R. A. of a point on the Meridian of the place, at the time of observation); from this, increased by 24h. if necessary, subtract the Sun's R. A., and the remainder is the "Apparent Time." In this case it is 16h. 49m. 50s, or 4h. 49m. 50s. P.M.

N.B.—It is useful practice to *work out* a few cases such as those given below, with the Slide Rule, and compare with the result by logarithms; remembering that the final logarithm is "log. sine of $(\frac{1}{2}A)^2$." Instead of dividing this log. by 2 (*i. e.* extracting its Square Root), and obtaining $\frac{1}{2}$ A, and then doubling to obtain A, and then reducing arc into *time*—the whole is done in Nautical works by a *Table* of "Log. sine square" (or XXXI. of Norie), which gives at once, the *time* corresponding to $(\frac{1}{2}A)^2$. Thus, in the preceding Example, the last log. given, is 19·479639, which is log. sine A^2; but to compare with the Slide Rule work which gives Nat. Sin. $\frac{1}{2}$ A, we divide 19·479639 by 2 (*i. e.* extract its Square Root), and get 9·7398195; and a Table of Logarithmic Sines shews this to be 33° 19′ 11·5″ or $\frac{1}{2}$ A; the result by the Slide Rule being 33° 20′, as shewn above.

Examples for exercise:

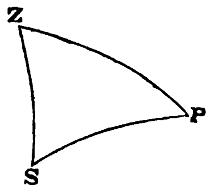
	°	′	″	°	′	″	°	′	″	°	′	″	°	′	″
Zen. Dist. ...	53	9	00	43	18	00	68	20	00	41	17	00	63	31	00
Pol. Dist.....	70	6	00	70	37	00	74	41	00	107	58	00	104	28	00
Co-Lat.	47	50	00	57	44	00	61	15	00	83	2	00	62	45	00
$\frac{1}{2}$ A =	28	54	45	23	10	30	36	41	00	16	40	00	24	41	45
	°	′	″	°	′	″	°	′	″	°	′	″	°	′	″
Zen. Dist. ...	67	21	00	62	32	00	66	59	00	74	28	00	51	33	00
Pol. Dist.....	111	45	00	73	27	00	96	31	00	84	24	00	74	9	00
Co-Lat.	54	5	00	52	47	00	46	30	00	39	14	00	55	13	00
$\frac{1}{2}$ A =	18	23	10	33	53	00	24	41	38	36	6	30	26	55	30

(II.) To find the Azimuth.

The Azimuthal angle is reckoned from the North in N. Lat., and from the South in S. Lat.; but if it exceeds 90°, it is generally read as a Compass reading. If for instance, it is found S. 110° E., it is read as N. 70° E.

It may be observed at sea, with a prismatic compass and reflector, by standing with the back to the sun; the reading has of course to be reversed. Thus, if the reading is 250°, or S. 70° W., the Azimuth is N. 70° E. The vibration of the card need cause no difficulty; for take a = reading at one extreme, b at the other extreme, and c the next vibration near the first, and $\frac{a + 2b + c}{4}$ = the mean reading. Thus, if the readings are 80° 40′,—80° 22′,—80° 36′, the mean is 80° 30′. This is the *compass* bearing. See APPENDIX E.

The oblique spherical triangle is the same as that in page 50; but in this case, A the required angle, is opposite the side PS or the Polar distance, or a. The Formula is the same, viz.,



$$\text{Sin. } \tfrac{1}{2} \text{ A} = \sqrt{\frac{\text{sin. } (h - b) \times \text{sin. } (h - c)}{\text{sin. } b \times \text{sin. } c}}.$$

Ex. 47.—In Lat. 10° 35′ S., the Sun's declination being 23° 33′ N., and the *true* altitude of the Sun's centre 13° 28′, required the Azimuth.

a = Pol. Dist. =	113° 23′		All these are taken out from the extra line of Sines at the back of the Trigonometrical Slide.
b = Zen. Dist. =	76 32	Nat. Sine ·973	
c = Co-Lat. =	79 25	Nat. Sine ·983	
	2)269 20		
h =	134 40		
$h - b$ =	58 8	Nat. Sine ·850	
$h - c$ =	55 15	Nat. Sine ·822	

Then $\tfrac{1}{2}$ A $= \sqrt{\frac{\cdot 850 \times \cdot 822}{\cdot 973 \times \cdot 983}} = \sqrt{\frac{\cdot 850 \times \cdot 822}{\cdot 955}}$ (for ·973 × ·983 by Slide $\frac{\text{A}}{\text{B}}$ = ·955).

A		·850
B		·955
C	·822	
D	·855 = $\tfrac{1}{2}$ A	

Then on the Trigonometrical Slide, ·855 = 58° 40′ = $\frac{1}{2}$ A; whence A = S. 117° 20′ E., or N. 62° 40′ E. the true Azimuth The *correct* value is N. 62° 38′ E.; and if the *observed* azimuth is N. 80° 30′ E., the "variation of the compass"* is 17° 52′ Westerly.

Ex. 48.—In Lat. 41° 53′ N., the Sun's declination being 19° 50′ and altitude of centre 44° 7′; required the true Azimuth.

a = Pol. Dist. 70° 10′
b = Zen. Dist. 45° 53′ Nat. Sine ·718
c = Co-Lat. 48° 7′ Nat. Sine ·745

2) 164° 10′

h = 82° 5′
$h - b$ = 36° 12′ Nat. Sine ·591
$h - c$ = 33° 58′ Nat. Sine ·559.

Then $\frac{1}{2}$ A $= \sqrt{\frac{\cdot591 \times \cdot559}{\cdot718 \times \cdot745}}$, and ·718 × ·745 by Slide $\frac{A}{B}$ = ·534.

Then $\frac{1}{2}$ A $= \sqrt{\frac{\cdot591 \times \cdot559}{\cdot534}}$

A		·591
B		·534
C	·559	
D	·785 = $\frac{1}{2}$ A	

The Trigonometrical Slide shews ·785 to be the Nat. Sine of 51° 45′ = $\frac{1}{2}$ A; whence A = N 103° 30′ W., or S. 76° 30′ W. The *correct* value is S. 76° 26′ W. and if the *observed* azimuth is 56° 15′ W. the "variation" of the Compass, is 20° 11′ Easterly.

Examples for exercise.

	°	′	″	°	′	″	°	′	″	°	′	″	°	′	″
Polar Dist...	69	58	00	101	00	00	67	40	00	70	43	00	67	2	00
Zen. Dist....	49	35	00	51	49	00	49	50	00	64	20	00	71	13	00
Co-Lat.	38	30	00	49	52	00	34	2	00	33	54	00	39	13	00
$\frac{1}{2}$ A =	55	10	30	5	39	30	55	35	27	46	40	7	38	12	4

* For remarks relative to "Variation," see Appendix E.

RATE OF MOTION IN ALTITUDE.

The Rate in ′ of *Arc*, is = Cos. Lat. × Sin. Azimuth × 15, in 1 minute of *Time*; a form easily solved by the Slide Rule.

I. *On the Equator. On Prime Vertical.*

Here the Co-latitude and the Azimuth = 90°, and their Sines 1 each; so that the rate at which the Sun or a Star rises or falls is 15′ of Arc, in 1m. of Time.

II. *On the Equator. Not on Prime Vertical.*

Here Co-latitude = 90° and its Sin. = 1; thus the Rate is Sin. Azim. × 15; or with an Azimuth of N. 24° E. the rate is ·407 × 15, or 6·1′ in 1 minute of Time.

III. *Not on the Equator. On Prime Vertical*

Here Azim. = 90°, and its Sine = 1. Hence the Rate is Sin. Co-lat. × 15. Thus in Lat. 34°, the Rate is ·829 × 15, or 12·4′ in 1 minute of Time.

IV. *Neither on the Equator, nor on the Prime Vertical.*

Say Lat. 35°, Azimuth N. 80° E. The answer is Sin. 55° × Sin. 80° × 15; or $\frac{\cdot 819 \times \cdot 985}{\cdot 0667}$ = 12·1′ of Arc, in 1 minute of Time.

N.B.—No heavenly body should be observed for "Time," when its rate of rising or falling is slower than 6′ of Arc, in 1 minute of Time.

To find the Azimuth.

By *reversing* the above operation, we can find the Azimuth approximately, when the rate of motion in altitude is known. This may be sometimes useful, when in taking altitudes for Lunars or other purposes, the Azimuth observation has been omitted.

Example. In Lat. 15° 10′ S. a set of sights gave the Sun moving in altitude 11·2′ of Arc, in 1m. of Time, and the Moon 8·7′ of Arc in 1m. of Time. Here Sin. Azim. $= \frac{\text{No. of } 1' \text{ in } 1\text{m}}{\text{Sin. Co-lat.} \times 15}$. The Slide Rule shews Sin. 74° 50′ = ·969, and this multiplied by 15 with the other Slide, shews 14·5 as the Divisor. Then the Slide set as follows, gives both answers:—

A	·602	·774	1
	8·7	11·2	14·5

And the Trigonometrical Slide gives for ·602 and ·774, the Sines of Azimuths 37°, and 50° 45′.

SLIDING GUNTER.

The "Sliding Gunter" formerly used by seamen, has, on the Slide, a line of SINES, and on the Stock, over (or sometimes under) it, a similar line of SINES; with these two lines, the first and second operations of the Example given below, were worked. Over (sometimes under) the line of SINES on the Stock, is engraved a line V. S. (Versed Sines), so arranged, that if any angle were selected on the line of Sines, as $= (\frac{1}{2} A)^2$, the angle over it on the line V. S. would be the *complement* of A. With these two lines, the third part of the operation in the Example below, is worked.

With reference to problems in Spherical Trigonometry, it will be observed from pages 51 and 52, that if we can once get $(\frac{1}{2} A)^2$, it will be convenient to be able to take out at once the angle A. This is done (in working by logarithms) by such Tables as XXXI. of Norie, or "Log. Sine Square" of Raper. The Sliding Gunter line V. S. does it also, but it gives the *complement* of A, instead of the angle itself.

Example. Take Ex. 46, page 51.

Zen. Dist.	66°	6′
Pol. Dist.	84	26
Co-Lat.	71	42
2)	222	14
	111	7
1st rem.	26	41
2d rem.	39	25

First. Sin. Pol. Dist. × Sin. Co-lat.; or Rad. : P D :: Sin Co-lat. : *Arc* 1*st*.

SIN	70° 54′ = arc 1st	84° 26′
SIN	71° 42′	90° = Rad.

Second. $\frac{\text{Sin. 1st rem.} \times \text{Sin. 2d rem.}}{\text{Arc 1st}}$, or Arc 1st : Sin. 1st rem. :: Sin. 2d rem. : *Arc 2d.*

SIN	17° 34′ = arc 2d	26° 41′
SIN	39° 25′	70° 54′

Third. To find the supplement of A, from 17° 34′ Arc 2d or $(\frac{1}{2}\text{A})^2$.

V. S.	113° 22′ = suppl. of A
SIN	17° 34′ = $(\frac{1}{2}\text{A})^2$

Then 180° − 113° 22′ = 66° 38′ = A, the Hour angle sought.

It will be seen that the operation is in fact, the same as in p. 51; namely, first $b \times c$, and then $\frac{(h-b) \times (h-c)}{b \times c} = (\frac{1}{2}\text{A})^2$, or ·302 = Nat. Sin. of 17° 34′.

When once $(\frac{1}{2}\text{A})^2$ is found, we can also obtain $\frac{1}{2}$ A on the line SIN: by measuring halfway between $(\frac{1}{2}\text{A})^2$ and 90°: for the line of Sines being a logarithmic scale, halving it is the same as taking the Square Root. Thus, halfway between 17° 34′ and 90°, is 33° 19′ = $\frac{1}{2}$ A.

In practice, the 1 foot improved Slide Rule is found to work with more quickness, and far more accuracy, than a Sliding Gunter of 2 feet, an expensive and unwieldy instrument.

The line V. S. (Versed Sines) on Gunter's Scale, is not a line of Versed Sines corresponding to the angles below it on line SIN, but it is a line of *half* the Versed Sines of the *supplements* of the angles below it on SIN. Thus, what is marked on V. S. as 113° 22′, is half

the Versed Sine of 66° 38′. It is in fact ·302* of the Radius, and exactly under its supplement, or 113° 22′, is 17° 34′, the Nat. Sine of which is also ·302 of the Radius.

So if we take 10° 3′ on line SIN. Its Nat. Sine is ·1746. Double this, and we have ·3492, which is the Versed Sine of 49° 24′, whose supplement 130° 36′ on V. S. is just over 10° 3′ on SIN.

Again, take the 8th Example in the List, in page 52; the result by the improved Slide Rule is

$$\frac{\cdot 853 \times \cdot 147}{\cdot 994 \times \cdot 725} = \cdot 1746 = \text{sin.}\,(\tfrac{1}{2}\,A)^2,$$

or, $$\sqrt{\frac{\cdot 853 \times \cdot 147}{\cdot 721}} = \cdot 4178 = \text{sin.}\ 24^\circ\,42' = \tfrac{1}{2}\,A,$$

whence A the Hour angle = 49° 24′.

By Gunter's Scale:

SIN	46° 7′ = arc 1st	83° 29′ = P. D. †
SIN	46° 30′ = Co-lat.	90° Rad.

	10° 3′ = arc 2d	58° 30′ = 1st rem.
SIN	8° 29′ = 2d rem.	46° 7′ = Arc 1st

V. S.	130° 36′
SIN	10° 3′ = $(\frac{1}{2}A)^2$

Then 180° — 130° 36′ = 49° 24′ = A the Hour angle. In practice, the results by the Gunter, as before stated, are anything but accurate, though the *theory* of the lines is strictly so.

---

* The Versed Sine of an angle is Radius *minus* the Cosine of that angle. Hence, if we want the Versed Sine of 66° 38′, its Nat. Cosine (or Nat. Sine of 23° 22′) is ·3966. Deduct this from 1·0 or Radius, and we have ·6034 as the V. S. of 66° 38′.

† As explained in page 2, 96° 31′ (the Pol. Dist.) being too large a figure for the line of Sines, we use the Sine of its supplement, which is the same thing.

APPENDIX.

APPENDIX A.

Brief explanation of the face of the Rule which has on it the Slide $\frac{B}{C}$.

For full details, refer to the "Hand-book of the Slide Rule."

THE line A on the upper Stock, and the lines B, C on the Slide, are identical. If on either of these lines we consider the 1 on the extreme left as 1, that in the middle will be 10, and that on the extreme right will be 100. If the 6 on the first radius be read as 60, the 6 on the second radius will be 600; the progression being by tens, either backwards or forwards. So if we consider the 8 on the second radius to be ·8, the 8 on the first radius will be ·08.

The values of the subdivisions between the figures, are soon observed. For instance, between 4 and 5 are ten spaces; so if 4 be read as 40, the first mark is 41, the next 42, and so on. Again between 2 and 3 are twenty spaces; so if the 2 is read as 20, the first mark (a short one) is 20·5; the next (a long one) 21·0; the next (a short one) 21·5, and so on. If we want to point out 3325, we consider the 3 on either radius as 3000; three of the longer divisions will bring us to 3300, and half-way between this and the next short division (which itself would be 3350), is 3325. It might be 33·25, 3·325, 33250 &c., according to the value assigned to the 3. The numbers with which beginners make most mistakes, are 12·5, 103, 11·1 &c.

Let the Slide be drawn out, to the right or to the left, and to *any extent;* and let a b represent *any* two numbers on the line A, and c d the two numbers on B under them;

$$\text{or } \frac{\text{A} \quad a \quad\rule{6cm}{0.4pt}\quad b}{\text{B} \quad c \quad\rule{6cm}{0pt}\quad d}. \quad \text{Then observe}$$

$$\left.\begin{array}{l} c : a :: d : b, \text{ — or } d : b :: c : a \\ a : b :: c : d, \text{ — or } b : a :: d : c \end{array}\right\} \begin{array}{ll} b = \dfrac{a \times d}{c}, & a = \dfrac{b \times c}{d} \\ c = \dfrac{a \times d}{b} & d = \dfrac{b \times c}{a}. \end{array}$$

$$\frac{a}{c} = \frac{b}{d}, \text{ and } \frac{c}{a} = \frac{d}{b}.$$

All this had better be *tried*, by an example; for instance, let 4 on B be set under 50 on A. Then we have

A	6	10	12·5	15	37·5	(50)	70	75	95	170
B	·48	·8	1	1·2	3	(4)	5·6	6	7·6	13·6

Here the "proportions" above noted, are seen at once. 3 : 37·5 :: 6 : 75, or 70 : 95 :: 5·6 : 7·6 &c. Fig. 1 in the Plate, represents the Slide set exactly as above; and *thus set*, it will solve *all* the examples in the next four pages, except where the Slide is *inverted*.

Refer to the setting of the Rule shewn in Fig. 1 *of the Plate.*

Multiplication

Mult. 12·5 by 4.

A	One multiplier	*Product*
B	1	Other multiplier
A	12·5	50 = *Ans.*
B	1	4

Division

Divide 136 by 8.

A	1	*Quotient*
B	Divisor	Dividend
A	1	17 = *Ans.*
B	8	136

Reduction

Reduce $\frac{7\frac{1}{2}}{60\text{ths}}$ to a decimal.

A	Numerator	*Decimal*
B	Denominator	1000ths
A	7·5	125
B	60	1000 = ·125 *Ans.*

In like manner the "reciprocal" of ⅛ is found to be ·125.

Rule of Three

4 : 50 :: 5·6 : x

A	Either middle Term	Last Term x
B	First Term	Either middle Term
A	50	70 = x
B	4	5·6

$x = \dfrac{b \times c}{a}$, or $\dfrac{c \times b}{a}$

$x = \dfrac{37·5 \times 7·6}{3}$

A	b	x
B	a	c
A	37·5	95 = *Ans.*
B	3	7·6

Multiply 12½ by 4, by 5·6, by 7·6 and by 12.

A	12·5	50	70	95	150 *Answers.*
B	1	4	5·6	7·6	12

Solve $\frac{37{\cdot}5 \times 4}{3}$, $\frac{37{\cdot}5 \times 4{\cdot}8}{3}$, $\frac{37{\cdot}5 \times 6}{3}$ *all at once.*

A	37·5	50	60	75 *Answers.*
B	3	4	4·8	6

Divide 288 by 12, by 26, by 36, and by 64. *Invert the Slide.*

A	$\left(\frac{1}{288}\right)$	12	36	64
D		24	8	4·5 *Answers.*

Divide 6^2 by 4·8, or $\frac{6 \times 6}{4{\cdot}8}$

A	6	7·5 = *Ans.*
B	4·8	6

Divide 24^2 by 8, by 9, by 12, and by 16. *Invert the Slide.*

A	$\left(\frac{24}{24}\right)$	36	48	64	72 *Answers.*
D		16	12	9	8

LINE D.

If the lines C and D are set even, the numbers on C are the *Squares* of the numbers under them on D; and the numbers on D are the *Square Roots* of the numbers over them on C. The 1 on the extreme left of C represents ·01, —1, —100, —10000; and the 1 in the middle of C represents 10, —1000, —100000; so if we want the Square Root of 2200, we look under the *second* radius of C, and find 46·9.

The line D, with C only, reads as follows:

C	a	b	$c^2 : d^2 :: a : b$
D	c	d	$\sqrt{a} : \sqrt{b} :: c : d$

So that with these *two* lines, D and C, we solve all cases of $x = \frac{m^2 \times o}{r^2}$, and $x = \frac{\sqrt{t} \times m}{\sqrt{e}}$.

(See Fig. 1 of the Plate; which will do for all the following, except where the Slide is *inverted.*)

Find the Square of $\frac{75}{112}$, or $\left(\frac{75}{112}\right)^2$

C	1	·45 = *Ans.*
D	112	75

or this may be read as ·01 over 11·2.

Find Square Root of $6\frac{7}{8}$, or $\sqrt{\frac{55}{8}}$

C	8	55
D	1	2·62 = *Ans.*

or this may be read as 800 over 10.

Multiply $2{\cdot}5^2$ by 8.

C	8	50 = *Ans.*
D	1	2·5

Multiply $\sqrt{16}$ by 11·2.

C	1	16
D	11·2	44·8 = *Ans.*

Divide 6^2 by 48, or $\frac{6 \times 6}{48}$ with A and B, as in the 3d and 4th Examples, p. III.

Divide 45000 by 75^2.

C	8 = *Ans.*	45000
D	1	75

Divide 10 by $\sqrt{80}$.

C	1	80
D	1·12 = *Ans.* (1·118)	10

Find the "Geometric Mean" of 125 and 180; or $x = \sqrt{125 \times 180}$

C	·125	180
D	125	150 = *Ans.*

Solve $x = \frac{72 \times 26^2}{30^2}$

C	54 = *Ans.*	72
D	26	30

Solve $x = \frac{\sqrt{26} \times 68}{\sqrt{37}}$

C	26	37
D	57 = *Ans.*	68

Solve $\frac{2{\cdot}5 \times 18}{1{\cdot}5^2}$ $\frac{3{\cdot}5 \times 18}{1{\cdot}5^2}$ $\frac{4{\cdot}6 \times 18}{1{\cdot}5^2}$, *all at once.*

C	$\left(\frac{18}{1{\cdot}5}\right)$	50 = x	98 = y	169 = z
D		2·5	3·5	4·6

Divide 43560, by 33^2, 42^2, 50^2. *Invert the Slide.*

Ↄ	$\left(\frac{43560}{1}\right)$	40 = x	24·13 = y	17·42 = z
D		33	42	50

Divide 42 by $\sqrt{36}$, $\sqrt{49}$, $\sqrt{196}$. *Invert the Slide.*

Ↄ	$\left(\frac{1}{42}\right)$	196	49	36 *Answers.*
D		3	6	7

Divide $\sqrt{2824}$ by $\sqrt{7{\cdot}5}$, $\sqrt{8}$, $\sqrt{14}$. *Invert the Slide.*

Ↄ	$\left(\frac{2824}{1}\right)$	14	8	7·5
D		14	18·8	19·4 *Answers.*

Divide $(8 \times \sqrt{144})$ by $\sqrt{36}$, $\sqrt{64}$, $\sqrt{256}$. *Invert the Slide.*

Ↄ	64	36	256	$\left(\frac{144}{8}\right)$—
D	12	16	6	

The line D with C, B, A, reads as follows:

A	a		
B	b		$a : b :: d^2 : c$
C		c	
D		d	$\sqrt{b} : \sqrt{a} :: \sqrt{c} : d$

Hence with these *four* lines, we solve $\frac{r \times o}{m^2}$, $\frac{n \times h^2}{s}$, $\frac{\sqrt{p} \times \sqrt{t}}{\sqrt{v}}$.

Solve $x = \frac{3{\cdot}8 \times 9{\cdot}5}{2{\cdot}18^2}$

A		9·5
B		7·6 = *Ans.*
C	3·8	
D	2·18	

Solve $x = \frac{4}{5}$ of $5{\cdot}7^2$

or $x = \frac{4 \times 5{\cdot}7^2}{5}$

A	5	
B	4	
C		26 = *Ans.*
D		5·7

Solve $x = \sqrt{\frac{15 \times 1620}{12}}$

or $\frac{\sqrt{15} \times \sqrt{1620}}{\sqrt{12}}$

A	15	
B	12	
C		1620
D		45 = *Ans.*

Solve $\frac{26 \times 40}{5{\cdot}7^2}$, $\frac{26 \times 45}{5{\cdot}7^2}$, $\frac{26 \times 65}{5{\cdot}7^2}$, *all at once.*

A		40	45	65
B		32	36	52 = *Ansrs.*
C	26			
D	5·7			

Solve $\frac{2{\cdot}74^2 \times 16}{6}$, $\frac{2{\cdot}74^2 \times 18}{6}$, $\frac{2{\cdot}74^2 \times 24}{6}$; *all at once.*

A		20	22·5	30 = *Ansrs.*
B		16	18	24
C	6			
D	2·74			

Solve $\sqrt{\frac{5}{4} \text{ of } 180}$, $\sqrt{\frac{5}{4} \text{ of } 320}$, $\sqrt{\frac{5}{4} \text{ of } 6200}$; *all at once.*

A	5			
B	4			
C		180	320	6200
D		15	20	88 = *Ansrs.*

Solve $\frac{220 \times 13}{18^2}$, $\frac{220 \times 13}{19^2}$, $\frac{220 \times 13}{20^2}$. *Invert the Slide.*

A			220
Ɔ			13
ꓭ	8·82	7·82	7·15 = *Ansrs.*
D	18	19	20

Solve $\frac{5 \times 6^2}{7}$, $\frac{5 \times 6^2}{9}$, $\frac{5 \times 6^2}{12}$. *Invert the Slide.*

A	7	9	12
Ɔ	25·7	20	15 = *Ans.*
ꓭ			5
D			6

Solve $\sqrt{\frac{6 \times 20}{5}}$, $\sqrt{\frac{6 \times 20}{8}}$, $\sqrt{\frac{6 \times 20}{14}}$. *Invert the Slide.*

A	6			
Ɔ	20			
ꓭ		14	8	5
D		2·74	3·87	4·9 = *Ans.*

Solve $\frac{24^2}{8}$, $\frac{24^2}{9}$, $\frac{24^2}{12}$, with Slide $\frac{ꓭ}{C}$ as in page III, Ex. 4th.

FORMULÆ.

In the "Hand-book of the Slide Rule," are given a great number of "FORMULÆ," to which the Slide Rule is particularly adapted, and which often supersede whole pages of "Tables." The following are a few:—

I.

A	22	Circumf. of circle
B	7	Diameter of circle

II.

C	43	Area of circle
D	7·4	Diam. of circle

III.

A	23	Statute miles
B	20	Nautical miles

IV.

C	20	Feet above Sea
D	6	Miles dist. of Horizon

V.

A	36	Cubic feet
B	224	Gallons (=1 ton)

VI.

A	6·4	Mètres
B	21	Feet

VII.

A	75	Kilogrammes
B	34	lbs. Avoir.

VIII.

A	Price in Francs	Shill. per yard
B	No. of Mètres	·721 (at 25 fr. = 1 £)

IX. Parallelopipeds

C	One side in inches	Gallons [Cubic Feet]
D	16·65 [41·57]	"Square side" in inches

X.

A	1·273	
B	Length of Cylinder	
C		Cubic content
D		Diam. of Cylin.

XI.

A	29·42	
B	Depth of Cylin. in feet	
C		Gallons
D		Diam. of Cyl. in inches

Thus, if as in Formula I. we set 7 on B under 22 on A, we have a "Table" shewing on the line A, the circumferences, to all the diameters on C, and *vice versâ*. So in Formula VII. we have a "Table" for reducing kilogrammes to lbs. Avoir. or *vice versâ*. By Formula VIII. if 13½ mètres cost 94*fr.* 50*c.* we know it is 5·125*s.* or 5*s.* 1½*d.* per yard. By Formula IV. if the eye is 20 feet above the sea, and a light known to be 125 feet above the sea, just visible on the horizon, the distance is 6·3 + 15·0 = 21·3 statute miles, or by Formula III. 18½ nautical miles. To exemplify Formula IX. if we have an iron tank measuring 9 ft. 4 in. by 6ft. 9 in. and 6 ft. deep, required its content in Cubic feet and in gallons. Reduce to inches; and find the "Square side" (being the Geometric Mean) of *any* two; say 72 and 81 inches, the Geom. Mean of which, as in the 17th of the preceding Examples, is 76·4 Then

C	112	[112]	2260 Gallons	[378 Cub. ft.]
D	16·65	[41·57]	76·4	[76·4]

So by Formulæ X. and XI. a Cylinder 2¼ feet deep, and 9½ inches diameter, has a content of 1910 cubic inches, ar 6·9 gallons.

Observe, that in using the Slide Rule, all the fractional parts must be reduced to decimals. Thus 4£ 17*s.* is 4·85£. For 6*s.* 3*d.* read 6·25*s.* For 5 lb. 8 oz. read 5·5 lbs. For 1 hr. 42 min. read 1·7 h. &c. For this purpose, the Rule itself may be used, as in the 3d Example, p. II.

LINE E.

If the line E on the *back* of the Slide is shut in even over D, it exhibits the *Cubes*, whilst D gives the Cube *Roots*.

E	a	b
D	c	d

$c^3 : d^3 :: a : b$

$\sqrt[3]{a} : \sqrt[3]{b} :: c : d.$

Mult. $4{\cdot}2^3$ by 8.

E	8	592·7 = *Ans.*
D	1	4·2

Divide 750 by 5^3.

E	6 = *Ans.*	750
D	1	5

$$x = \sqrt[3]{\frac{221}{\cdot 524}}$$

E	221	524
D	7·5 = *Ans.*	10

$$\left(\text{Here } \frac{\text{E} \;\; \cdot 524}{\text{D} \;\; 1} = \frac{\text{E} \;\; 524}{\text{D} \;\; 10}\right)$$

$$x = \frac{5^3 \times \cdot 7}{1{\cdot}97^3}$$

E	·7	11·45 = *Ans.*
D	1·97	5

LINE N.

When line N at the *back* of the Slide, is set even over D (or 4 under ·602), it gives the Logarithms of the numbers on D. So to raise 8 to the sixth power, or 8^6.

First.	Log. of 8.	N 1 | / D 1 |	·903 = *Ans.* / 8
Second.	·903 × 6	A ·903 / B 1	5·418 = *Ans.* / 6
Third.	Nat. number of 418	N 1 | ·418 / D 1 | 262 = *Ans.*	

The "Index" shewn in the *second* operation, being 5, the answer must have 6 figures, or 262000. The *true* answer is 262144.

Example. What will 450£ amount to in 6 years, at "Compound Interest" 4 per cent.? Here $x = 1{\cdot}04^6 \times 450$. The Logs. of 1·035 to 1·045 are printed or engraved on the instrument, so that we have $1{\cdot}04^6 = {\cdot}017033 \times 6 = {\cdot}1022$; and line N shews that the Nat. number of ·1022 is 1·265. Then $1{\cdot}265 \times 450 = 569$£, the *Answer.*

Example. What is the "present value" of an Annuity of 320£ for 18 years; rate of interest 3½ per cent.?

Here $x = 320 \times \dfrac{1 - \dfrac{1}{1{\cdot}035^{18}}}{{\cdot}035}$. The log. of $1{\cdot}035 = {\cdot}01494$ is printed on the Rule. Then $\cdot01494 \times 18 = 0{\cdot}269$, the complement of which is 9·731, which is the Log. of ·538, as shewn by line N. Then $1 - {\cdot}538 = {\cdot}462$; and $\dfrac{320 \times {\cdot}462}{{\cdot}035} = 4220$£, as in the 5th Example, page II. By a reverse process, in which the Slide Rule would be equally useful, we should find that the "Annuity" for 20 years, purchasable for 2000£, reckoning interest at 4 per cent.

would be $2000 \div \dfrac{1 - \dfrac{1}{1{\cdot}04^{20}}}{{\cdot}04}$, or $2000 \div \dfrac{{\cdot}5425}{{\cdot}04} = 147$£.

APPENDIX B.

REFRACTION. DIP. DISTANCE OF HORIZON.

"ASTRONOMICAL" Refraction is the apparent angular elevation of the celestial bodies above their true places, caused by the bending of the rays of light in their passage through the atmosphere. On the horizon it is greatest, being about 33′ or a sun's breadth, and at the zenith it is nothing. At an altitude of 10° it is 5′ 20″, and at 45¾° it is 1′ 00″. This supposes the temperature of the air at 50° Fahrenheit,* when the Refraction in″ equals Tan. Z. D. × 57·5 ;† a Formula well adapted to the Slide Rule.

TAN	Zen. Dist.	45°
A	Refr. in″	57·5

or reverse the Slide at the back (p. 3).

A	57·5	Refr. in″
: NVꓕ	45°	Altitude.

If there is no extra line of Tangents (p. 3) on the back of the Slide, and the *Zenith Dist. is above* 45°

TAN :	Altitude	45°
A	57·5	Refr. in″

Thus, Alt. 60°, refr. = 33″. Alt. 18°, refr. = 177″. Alt. 14°, refr. = 230″. Alt. 35° = 83″. Alt. 40° = 69″.

"Terrestrial" Refraction has reference, not to heavenly bodies beyond the Earth's atmosphere, but to bodies near the Earth's surface. Its effect is, to elevate the surface of the distant horizon

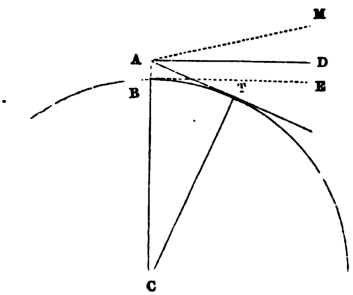
---

* The higher the temperature, the rarer the atmosphere, and the less the refraction. Thus, at an altitude of 21° we should have to deduct 5″ from the mean refraction, for every degree above 50°; and at an altitude of 33°, 3″ for every degree above 50°.

† At an altitude above 60°, the multiplier is 59; but *no* refraction at 90° alt.

at sea, or on a level expanse of land. Thus, in the following figure if the eye is at A, and AD a horizontal line, the surface of the horizon at T would appear to the eye higher than it really is ; that is, the angle of "Dip" DAT would be diminished. Terrestrial Refraction is generally estimated at $\frac{1}{12}$ of the "intercepted arc ;" * that is, if from B to T is 12 geographical (or nautical miles), the angle of Dip, DAT, would be decreased 1′ of arc. (The arc BT, or rather the angle C at the Earth's centre, is always equal to the true Dip, DAT, as will be presently shown.)

DIP.



In the figure, AT is the tangential line from A the eye of the observer, to the visible horizon at T, and the angle DAT is the Dip. If an object at M is observed, its apparent height above the horizon will, if there be no refraction, be MAT, which is greater than its real angle of elevation DAM, by the Dip DAT.

N.B.—The true Dip DAT is easily shewn to be equal to the "intercepted arc" BT, or in other words, to its angle at the centre of the Earth TCA. For $\angle$ DAT + $\angle$ TAC = 90°, and $\angle$ TAC + $\angle$ TCA = 90° ; whence, striking out $\angle$ TAC from each, we have $\angle$ DAT = TCA. So that if the true Dip is 6′, the distance AT (or BT—for the distance is practically the same) is 6 Nautical miles, of 20 to 23 Statute.

---

* The amount of Terrestrial Refraction is sometimes estimated at $\frac{1}{10}$th, and sometimes at $\frac{1}{14}$ of the "intercepted arc," *i. e.* $\frac{1}{10}$ or $\frac{1}{14}$ of the *true* Dip. The state of the atmosphere near the surface of the Earth varies so greatly and so rapidly, that there is no certainty in the estimate.

The *true* Dip to any height h (= AB in the figure), is thus obtained. From the above figure (where d = distance AT), CT : Radius :: AT : Tan. C; or Tan. C $= \frac{rad. \times d}{r}$.* We shall shew, when speaking of the "Distance of the horizon," page 72, that $d = \sqrt{2r \times h}$, whence Tan. C $= \frac{rad. \times \sqrt{2r \times h}}{r} = \frac{rad. \times \sqrt{2r} \times \sqrt{h}}{r}$ $= rad. \times \sqrt{h} \times \frac{\sqrt{2r}}{r} = rad. \times \sqrt{h} \times \frac{\sqrt{41777400}}{20888700} = rad. \times h$ $\times \cdot 003094$; whence Tan. C $= \sqrt{h} \times \cdot 0003094 \times$ radius. Now, as we want the Dip as an *angle*, and not as a *tangent*, we may, when the angle is so small, substitute the arc (and thence its angle) for the tangent, and consider the *arc* of C to be the tangent of C. If we want the true Dip in ′, we know that radius = an arc of 57·3°, or 3437·75′; whence the arc of C, or the true dip in′ when h is given in feet, is $\sqrt{h} \times \cdot 0003094 \times 3437{\cdot}75 = \sqrt{h} \times 1{\cdot}0637$; whence the formula

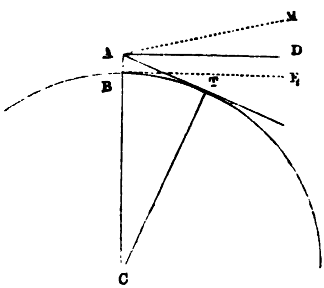
C	1	42	h in feet	$\left(\frac{30}{350''}\right)$
D	1·0637	6·9	True dip in′	

But the Dip is affected by Refraction, that is, it is lessened by about $\frac{1}{12}$ of itself (or $\frac{1}{12}$ of the "intercepted arc"), as shewn in page 70. The *apparent* Dip, therefore, or that which in practice has to be deducted from the angle of elevation of a heavenly body, when the eye of the observer is above the surface, is $\frac{11}{12}$ of the *true* Dip, or $\frac{11}{12}$ ($\sqrt{h} \times 1{\cdot}064$) when h is in feet, and angle of Dip in′. Hence the *apparent* Dip $= \sqrt{h} \times \cdot 975$. So if h = 127 feet, the *true* Dip is 12′, and the *apparent* dip 11′. The following is the Formula for the Slide Rule:

C	1	33	Height in feet	$\left(\frac{40}{370''}\right)$
D	·975	5·6	*apparent* dip in′	

* BC and CT each represent a radius of the earth = r, or 20888750 feet, giving a diameter of 41777400 feet, or 7912·4 statute, or 6875·5 geographical (or nautical) miles. d = distance AT.

DISTANCE OF THE HORIZON.



In the figure, let

r or BC or TC = radius of the earth.

h = AB, the height of the observer's eye.

d = AT, the distance of the visible horizon from the observer.

Then $h = \frac{d^2}{2r}$,

and $d = \sqrt{2r \times h}$

[It may be proved thus. The angle ATC being always a right angle, we have from Euclid I. 47 $(r \times h)^2 = r^2 + d^2$.

Expand $(r \times h)^2$; and $r^2 + 2rh + h^2 = r^2 + d^2$

or $2rh + h^2 = d^2$

or $2rh = d^2 - h^2$

Divide by $2r$, and $h = \frac{d^2}{2r} - \frac{h^2}{2r}$

But $\frac{h^2}{2r}$, even when h = 4 miles of elevation, is only $\frac{16}{7912 \cdot 4}$ statute miles, or $10\frac{1}{2}$ feet; so it may be omitted as a subtractive quantity; whence we have

$$h = \frac{d^2}{2r}; \text{ and } d = \sqrt{2r \times h}.$$

The same result is obtained from Euclid III. 36, by which $(2r + h) \times h = d^2$; whence $2rh + h^2 = d^2$. Omitting h^2 as an additive, being so small, we have $2rh = d^2$, or $d = \sqrt{2r \times h}$ as before.]

Now $2r$, or the diameter of the Earth, is 6875·5 geographical

or nautical miles ;* so that $h = \frac{d^2}{6876}$ in geographical miles. Or if we take h = height in *feet*, then $h = \frac{d^2 \times 6076}{6875{\cdot}5} = {\cdot}88376\, d^2$; and $d = \sqrt{1{\cdot}1315\, h}$, or $\sqrt{h} \times 1{\cdot}0637$; the same as the angle of *true* Dip. (N.B.—p. 71).

All the above supposes *no refraction*. The effect of this is, to decrease the value of h, or the amount of Earth's curvature, by $\frac{1}{6}$th or $\frac{1}{7}$th.† If we take $\frac{1}{6}$th, then *including refraction*, $h = \frac{5 \times {\cdot}884}{6} d^2$ or $\cdot 7364\, d^2$. Hence the formula

$$\begin{cases} \dfrac{A}{B} \qquad\qquad \dfrac{1}{\cdot 7364} \\ \dfrac{C}{D} \quad \dfrac{\text{Feet above sea (or curvature)}}{\text{Dist. of horizon, in Naut. miles}} \end{cases}$$

OR,

$$\frac{C}{D} \quad \frac{1}{1{\cdot}165} \quad \frac{9}{3{\cdot}5} \qquad \frac{\text{Height in feet, or curvature}}{\text{Dist. in Naut. miles}}$$

It is sometimes useful in *Surveying*, to use *Statute* miles. In this case, $h = \frac{d^2 \times 5280}{7912{\cdot}4} = {\cdot}6673\, d^2$ or $\frac{2}{3}\, d^2$,

and $\quad d = \sqrt{1{\cdot}50\, h}$, or $\sqrt{h} \times 1{\cdot}224$, or $\sqrt{\frac{3 \times h}{2}}$.

This supposes *no refraction*, and gives a curvature to the earth of a fall of 8 inches in a statute mile, or $\frac{1}{10}$ of an inch in 200 yards. Assuming the effect of refraction, as above given, to decrease the

---

* The geographical or nautical mile is 6076 feet. The statute mile is 5280 feet; a proportion of 69·05 to 60, or 23 to 20.

† If we assume $\frac{1}{7}$th, $h = {\cdot}758\, d^2$ or $\frac{C}{D} \; \frac{9{\cdot}25 = h \text{ in feet}}{3{\cdot}5 = d \text{ in N. miles}}$. If $\frac{1}{6}$th is allowed, it is about equivalent to a refraction of $\frac{1}{12}$ of the intercepted arc, added to d. For example, if h = 127 feet, and *no* refraction, d = 12 Naut. miles; *with* refraction 13·1 Naut. miles. Assuming $\frac{1}{7}$th, d would be 12·9 Naut. miles.

value of h or amount of curvature, by $\frac{1}{6}$th, we have *when refraction is included*, $h = \frac{5}{6}$ of $\frac{2}{3}d^2 = \frac{5}{9}d^2$. Hence the formula

A	9	
B	5	
C		h = feet above level
D		d = visible hor. in *Stat.* miles

OR

C	5	h = feet above level
D	3	d = visible hor. in *Stat.* miles

(Sometimes the refraction is estimated to decrease the curvature by $\frac{1}{7}$th; in this case $h = \frac{6}{7}$ of $\frac{2}{3}d^2$, or $\frac{4}{7}d^2$.) If the wire of a Levelling instrument coincides with a line or mark, one statute mile off, that line will not be 8 inches higher from the surface than the line of the instrument, (as it would be if there were no refraction,) but it will be $6\frac{2}{3}$ inches only, higher from the surface of the earth. This $6\frac{2}{3}$ inches in 1 mile, is equal to $\frac{1}{10}$ inch in 215 yards, or $\frac{1}{100}$ of a foot in 234 yards.

Inaccessible Distances.

The following Formulæ are founded on the fact that the *arc* of an angle of 57·296 degrees, is equal to the Radius, or in other words that the arc subtended by an angle of 1″ is equal to $\frac{1}{206264 \cdot 8}$ of the Radius. These Formulæ are only adapted to angles under 3°; for in such small angles the *chord* subtended, is equal, for all purposes, to the *arc*.

A	Angle in ″	Height of object
B	206265	Distance

A	Angle in ′	Height or subtense
B	3437·7	Distance

A	Angle in ′	Subtense in feet
B	1146	Distance in yards

A	Angle in ′	Subtense in feet
B	·651 [·566]	Dist. in Stat. miles [Naut. miles]

Thus by Formula 3d, if a man 6 feet high subtends an angle of 6·9′, his distance is 1000 yards; and a foot rule at the distance of 1 mile, will subtend 39″, or ·651′. Again, if a vessel known to be 150 ft. long, subtends an angle of 42·5′; her distance is 2 Nautical miles.

A vessel of about 1000 tons, is observed just hull down, and an angle taken from the sea to her main-topsail yard is 8′ 30″. Supposing the yard to be 100 feet above deck, what is her distance in Nautical miles?

A	8·5	100
B	·566	6·66 *miles*

To find Distances and Heights at Sea.

When the height of a distant mountain is known, and its angle observed, some very elaborate rules are given in a pamphlet by the late Lieut. Raper, and in the "Admiralty Manual," for finding the Distance in Nautical miles. The very great uncertainty as to the amount of "Terrestrial refraction" (N.B. p. 69) renders such very close calculations quite as liable to an error of a mile or so, as the following short method by the Slide Rule, by "trial and error:"

[I.]	A	Angle (corrected for true Dip) in ′	Height in feet $= x$	(p. 75.)
	B	·566	Dist. in Naut. miles	
[II.]	C	9	Feet above level $= y$	(p. 73.)
	D	3·5	Dist. in Naut. miles	

We suppose the *estimated* Distance given to within 4 or 5 miles. Then if we can get x by [I.] and y (by II.), to equal, *together*, the known height of the mountain, the Distance taken is correct.

Example. Diana's Peak at St. Helena is known to be 2700 feet high. It was observed from a ship's deck, the eye 20 feet above the sea, at an angle of 1° 16′ 46″; the *estimated* distance being 16

Nautical miles. Angle corrected for true Dip (p. 71) = 1° 16′ 46″ − 4′ 46″ = 1° 12′.

$$[\text{I.}]\quad \frac{A \quad 72'}{B \quad \cdot566} \qquad \frac{2035 = x}{16}$$

The true Dip having been subtracted from the observed angle, the result is as if the eye were at B (fig. page 72), and we were measuring an "inaccessible distance" (page 74).

The 2035 feet is therefore the subtended portion of the mountain which is visible above the horizon. But now we have to add the portion concealed from view by the curvature of the Earth, as in page 73.

$$[\text{II.}]\quad \frac{C \quad 9}{D \quad 3\cdot5} \qquad \frac{188 = y}{16}$$

Then 2035 + 188 = 2223 ; which *won't do*, for the given height is 2700 feet. It is evident we have assumed too short a distance. Then try 19 miles, and we have

$$[\text{I.}]\quad \frac{A \quad 72'}{B \quad \cdot566} \qquad \frac{2417 = x}{19}$$

$$[\text{II.}]\quad \frac{C \quad 9}{D \quad 3\cdot5} \qquad \frac{265 = y}{19}$$

Then 2417 + 265 = 2682 or within 20 feet of the given height, so that we are sure that 19 Nautical miles, is as near the true Distance as could be obtained by mathematical computation of some length.

Example (from the Admiralty Manual). Mount Etna, said to be about 19000 feet high, was observed at an angle of 1° 30′ ; the eye being 20 feet above the sea. Estimated distance 55 nautical miles. Corrected angle 1° 30′ − 4′ 45″ = 1° 25′ 15″. (This true Dip 4′ 45″ is found by the Formula, p. 71.)

$$[\text{I.}]\quad \frac{A \quad 85\cdot25}{B \quad \cdot566} \qquad \frac{8300 = x}{55}$$

$$[\text{II.}]\quad \frac{C \quad 9}{D \quad 3\cdot5} \qquad \frac{2225 = y}{55}$$

But 8300 + 2225 equals 10525 which is not enough, and shews that the estimated distance is too small. Try 57 miles for Distance.

$$[\text{I.}]\quad \frac{\text{A} \quad 85{\cdot}25}{\text{B} \quad {\cdot}566} \quad \frac{8590 = x}{57}$$

$$[\text{II.}]\quad \frac{\text{C} \quad 9}{\text{D} \quad 3{\cdot}5} \quad \frac{2390 = y}{57}$$

Here 8590 + 2390 = 10980 feet for Etna's height, which is so near the truth, that the last assumed Distance 57 Nautical miles, may be considered *correct*. The elaborate computation in the "Admiralty Manual," makes it 57 miles distant, at a height of 10956 feet.

Example (from the Admiralty Manual). Snowdon, whose height is 3565 feet, was observed at an angle of 45′ 05″, the eye being 14 feet above the surface. Estimated Distance 40 miles. True dip to 14 feet by Formula in p. 71 = 4′ 05″, making the corrected angle 41′.

$$[\text{I.}]\quad \frac{\text{A} \quad 41'}{\text{B} \quad {\cdot}566} \quad \frac{2900 = x}{40}$$

$$[\text{II.}]\quad \frac{\text{C} \quad 9}{\text{D} \quad 3{\cdot}5} \quad \frac{1175 = y}{40}$$

Here $x + y$ gives 4075 feet for the height of Snowdon, which is too great, shewing that the assumed distance 40 miles is too great. Try 35 miles.

$$[\text{I.}]\quad \frac{\text{A} \quad 41'}{\text{B} \quad {\cdot}566} \quad \frac{2540 = x}{35}$$

$$[\text{II.}]\quad \frac{\text{C} \quad 9}{\text{D} \quad 3{\cdot}5} \quad \frac{900 = y}{35}$$

Here $x + y$ gives 3440, which is too little, and the assumed distance too small. Try 36 miles.

$$[\text{I.}]\quad \frac{\text{A} \quad 41'}{\text{B} \quad {\cdot}566} \quad \frac{2600 = x}{36}$$

$$[\text{II.}]\quad \frac{\text{C} \quad 9}{\text{D} \quad 3{\cdot}5} \quad \frac{955 = y}{36}$$

Here $x + y = 3555$, or only 10 feet difference from the required height; so that the last assumed Distance, 36 Nautical miles, may be considered correct. By the "Admiralty Manual" it is 35·6 miles.

N.B.—It is to be observed that in the more elaborate mathematical solutions of this problem, the *estimated distance* is not given; but *in practice*, the distance is always known within 4 or 5 miles, and though 3 or 4 trials may be required by the Slide Rule to obtain $x + y =$ the height of the mountain, it will not occupy more time than 2 or 3 minutes.

If the Distance is known, and the Height of the mountain required from the observed angle, the solution is simple with the Slide Rule.

Example. Distance known to be $13\frac{1}{2}$ Nautical miles. The observed angle 2° 4′ 25″. Eye elevated 20 feet. Here the angle corrected for True Dip to 20 feet (p. 71), is 2° 4′ 25″ — 4′ 45″ = 1° 59′ 40″.

A	119·7′	$2860 = x$
B	·566	13·5

C	9	$133 = y$
D	3·5	13·5

and $x + y = 2993$, the Height required. By mathematical computation it was 3000 feet; but owing to the uncertainty of Terrestrial refraction, 2993 is as likely to be right as 3000.

APPENDIX C.

Multiplication, Division, &c. of Angles.

a = the Angle required ; x = the number required.

Ex. 1.—Sin. $a = \frac{3}{4}$ Radius. (Here 4 : 3 :: radius (sin. 90°) : a.)

A	3	4
SIN	48° 36′	90°

Ex. 2.—Sin. $a = \frac{220}{350}$ (of Radius). Here 350 : 90° or radius :: 220 : a.

A	220	350
SIN	39°	90°

Ex. 3.—Cos. $a = \frac{103}{257}$ (of Radius). Here 257 : 103 :: radius (sin. 90°) : *complement* of the required angle.

A	103	257
SIN	23° 38′ which gives answer 66° 22′	90°

Ex. 4.—Tan. $a = \frac{134}{164}$ (of Radius). Here 164 : 134 :: Rad. (tan. 45°) : a.

TAN	39° 15′	45°
A	134	164

***Ex. 5.**—Tan. $a = \frac{390}{265}$ (of Radius). Here 265 : 390 :: Rad. (tan. 45°) : a.

TAN	45°	55° 45′
A	265	390

* When, as in Examples 5 and 6, the denominator (or divisor) is less than the numerator, and there is no *extra* line of Tangents on the back of

Ex. 6.—Tan. $a = 1\frac{1}{4}$ Radius, or $\frac{4}{5}$.

TAN	45°	51° 20′
A	4	5

Ex. 7.—$x = 229 \times \sin. 56° 15'$. (Here Rad. (or sin. 90°) : 229 :: sin. 56° 15′ : x.)

A	191	229
SIN	56° 15′	90°

Ex. 8.—$x = 6 \times \cos. 58°$. (Here Rad. (or sin. 90°) : 6 :: sin. compl. 58 : x.)

A	3·18	6
SIN	32° (compl. of 58°)	90°

Ex. 9.—$x = 5 \times \tan. 36° 30'$. (Here Rad. (tan. 45°) : 5 :: tan. 36° 30′ : x.)

TAN	36° 30′	45°
A	3·7	5

***Ex. 10.**—$x = 7 \times \tan. 57°$. (Here Rad. (tan. 45°) : 7 :: tan. 57° : x.)

TAN	45°	57°
A	7	10·8

---

the Slide (p. 4), we can only obtain with the usual line TAN, the *complement* of the answer. Thus, Ex. 5:

TAN	compl. of answer	45°
A	265	390

and

TAN	compl. of answer	45°
A	4	5

* When there is no *extra* line (p. 4), of Tangents, on the back of the Slide, we must, when the Tangent is above 45°, use the *complement* of the angle. Thus in Ex. 10:

TAN	33° (compl. of 57°)	45°
A	7	10·8

***Ex. 11.**—$x = 235 \times \text{sec. } 56^\circ\ 15'$. (Same as $\dfrac{235}{\text{sin. } 33\frac{3}{4}}$, Ex. 13).

Ex. 12.—$x = \dfrac{250}{\text{sin. } 22^\circ\ 30'}$. (Here sin. $22^\circ\ 30'$: 250 :: sin 90° (Rad.) : x).

A	250	·653
SIN	22° 30′	90°

Ex. 13.—$x = \dfrac{235}{\text{cos. } 56^\circ\ 15'} = 423$. Solved as $\dfrac{235}{\text{sin. } 33^\circ\ 45'}$. Exs. 11 and 12.

Ex. 14.—$x = \dfrac{250}{\text{tan. } 22^\circ\ 30'}$. (Here 250 : tan. 22° 30 :: Rad. (tan. 45°) : x).

TAN	250	45°
A	22° 30′	603

Ex. 15.—$x = \dfrac{\text{tan. } 27^\circ\ 30'}{\text{sin. } 70^\circ}$. (Here sin. 70° : 1 :: tan. $27^\circ\ 30'$: x).

A		1
SIN		70°
TAN	27° 30′	
	·554	

Ex. 16.—$x = \dfrac{\text{sin. } 64^\circ\ 10'}{\text{tan. } 26^\circ\ 34'}$. (Here tan. $26^\circ\ 34'$: 1 :: sin. $64^\circ\ 10'$: x).

A		1·8
SIN		64° 10′
TAN	26° 34′	
	1	

---

* Ex. 11 may also be solved with the Inverted Slide:

: NIS	90°	$33\frac{3}{4}^\circ$ = compl. $56\frac{1}{4}^\circ$
A	235	423 = x

Ex. 17.—$x = \dfrac{250 \times \sin. 67° 30'}{\sin. 22° 30'}$.

A	250	604
SIN	22° 30′	67° 30′

Ex. 18.—Sin. a = sin. 13° 4′ × ·1583. (Here 1 : ·1583 :: sin. 13° 4′ : sin. a).

A	·1583	1
SIN	2° 3′	13° 4′

***Ex. 19.**—Sin. a = sin. 51° 30′ × sin. 23° 28′. (Here it is necessary, first to find (as in p. 2) the Nat. sine of one of the angles,—say 51° 30′ = ·783 ; and then 1 : sin. 23° 28′ :: ·783 : sin a.)

A	·783	1
SIN	18° 10′	23° 28

Or the two Natural sines ·783 and ·398 may be taken out together, and then multiplied by the lines $\frac{A}{B}$ = ·312 ; the Nat. sine of which is 18° 10′.

***Ex. 20.**—Sin. a = tan. 31° 10′ × tan. 11° 14′. (Here it is necessary, first to find (as in p. 3) the Nat. tan. of one of the angles,—say 11° 14′ = ·199 ; and then 1 : tan. 31° 10′ :: ·199 : sin a.)

A	·199	
SIN	6° 54′	
TAN		31° 10′
A		1

Or the two Natural tangents ·199 and ·605 may be taken out together, and then multiplied by the lines $\frac{A}{B}$ = ·1203 ; the Nat. sin. of which is 6° 54′.

---

* In cases such as Examples 16 and 17, &c. where one of the two given angles is *constant*, that one should be selected for taking out the Nat. sine, or Nat. tangent.

Ex. 21.—Sin. a = sin. 18° × tan. 30°. First find the Nat. tan. of 30° (as in p. 3) to be ·577. Then 1 : ·577 :: sin. 18° : sin. a.

A	·577	1
SIN	10° 16′	18°

Ex. 22.—Sin. $a = \dfrac{\text{sin. } 39^\circ\ 30'}{4}$. Here 4 : 1 :: sin. 39° 40′ : sin. a.

A	4	1
SIN	39° 30′	9° 9′

***Ex. 23.**—Tan. a = tan. 77° × ·917. First find, as in p. 4, the Nat. tan. of 77° = 4·33. Then Rad. (tan. 45°) : 917 :: tan. 77° : tan. a.

TAN	75° 52′	77°
A	·917	1

Ex. 24.—Tan. a = sin. 45° 20′ × sin. 34° 3′. First find the Nat. sine of one of the angles—say 45° 20′ = ·711. Then 1 : sin. 34° 3′ :: ·711 : tan. a.

A		1
SIN		34° 3′
TAN	21° 43′	
A	·711	

†**Ex. 25.**—Tan. a = tan. 52° × tan. 61°. First find the Nat. tan. of one of the angles—say 52° = 1·28. (Here 1 : tan. 61° :: 1·28 : tan. a).

TAN	61°	66° 32′
A	1	1·28

---

* Should the tangent exceed 45°, and no extra line of Tangents (p. 4), the setting would be as follows:

TAN	23° (= compl. 77°)	14° 8′ = compl. of answer
A	·917	1

† Here, as both angles exceed 45°, if there is no extra line of Tangents (p. 4), we must find the Nat. tan. of *both* (as in p. 4), to be 1·28 and 1·8, and multiply them by the lines $\frac{A}{B}$ to get 2·304 the Nat. tan. of the answer.

Ex. 26.—Tan. a = sin. 18° $\times$ tan. 30°. First find the Nat. sine of 18° to be ·309. Then 1 : ·309 :: tan. 30° : tan. a.

TAN	10° 7′	30°
A	·309	1

Ex. 27.—Tan. $a = \frac{\text{tan. } 35°}{5}$. (Here 5 : 1 :: tan. 35° : tan. a).

TAN	7° 58′	35°
A	1	5

Ex. 28.—Sin. $a = \frac{\text{sin. } 23°}{\text{sin. } 51° \, 30'}$. First find Nat. sin. 51° 30′ = ·782, and then it becomes $\frac{\text{sin. } 23°}{\cdot 782}$ as in Ex. 22.

A	·782	1
SIN	23°	30°

Ex. 29.—Sin. $a = \frac{\text{tan. } 27° \, 30'}{\text{sin. } 70°}$. Here we must first find the *Numeral* answer ·554 (as in Ex. 15), which is the Nat. sin. of 33° 40′, (p. 2.)

Ex. 30.—Tan. $a = \frac{\text{tan. } 27° \, 30'}{\text{sin. } 70°}$. Here we must first find the Numeral answer ·554 (as in Ex. 15), which is the Nat. tan. of 29°.

Ex. 31.—Tan. $a = \frac{\text{sin. } 64° \, 10'}{\text{tan. } 26° \, 34'}$. Here we must first find the Numeral answer 1·8, which is (p. 4) the Nat. tan of 60° 57′.

Ex. 32.—Tan. $a = \frac{325 \times \text{tan. } 36° \, 30'}{1320}$. (Here 1320 : 325 :: tan. 36° 30′ : tan. a).

TAN	10° 19′	36° 30′
A	325	1320

APPENDIX D.

GREAT CIRCLE SAILING.

SINCE the meridians of the Earth are not parallel, but converge to the Poles, it follows that a line that crosses each meridian at the same angle, must be a curve, or portion of a spiral; and this is the case when sailing *on a Rhumb*. Though the course a vessel should steer to sail from one place to another on a Rhumb, is simple enough (it is, in fact, only to keep to one *compass* course throughout), it is not the course which makes the *shortest distance*. The shortest distance between two places on the surface of a sphere is the arc of the "great circle" that passes between them (which arc, if continued sectionally, would cut through the sphere at its centre); but to adopt this, requires that the compass course should be *perpetually changing*, and the labour of computing the track, and this constant change, renders "Great Circle" sailing unacceptable to seamen in general; especially as it seldom makes a difference of above 1 or 2 per cent. in the *distance*, and under the most favourable circumstances that can *practically* be adopted, not above 5 or 6 per cent.

A vessel sailing due N. or S. or on the Equator due E. and W., is sailing on a "great circle," and, in these cases, the usual method of sailing *is* Great Circle sailing.

To prove that the course when "sailing on a rhumb" is a curve, or portion of a spiral, mark on a Globe a spot on any of the Meridians; draw with a fine camel-hair brush, in water-colour, a line at an angle of 45° (or a N.E. course), till it reaches the next meridian. At this place draw another N.E. line to the next meridian, and so on, crossing *each meridian at the same angle*, *i.e.* 45°. This will represent the track of a ship sailing N.E. by compass, or sailing on a Rhumb. It will be seen that the line is a curve, or portion of a spiral round the Pole, and the nearer the meridians are laid down on the globe, the more evident will the case be. This kind of line is called a "loxodromic curve," and a ship sailing on it continuously,

would reach the Pole after circulating an infinite number of times round it.

To show the difference between the track of a vessel "sailing on a Rhumb," and the "Great Circle track," mark on a globe two places, each in Lat. 50° N. Stretch a thread across from one to the other; this will show the "great circle" route. The line engraved on the globe as the parallel of 50°, will show the line that a vessel sailing on a Rhumb would steer, and it will be seen that the distance on that line must be much greater than the distance shown by the thread, which will, in fact, appear as a line curving *away from* the Pole. If these two lines were laid down on a Mercator's Chart (which could easily be done by noting at what latitudes on the Globe the thread crosses every 4° or 5° Longitude), the "great circle" track would appear on the chart as a curve, *towards* the Pole, whilst the "rhumb line" track, or the parallel of latitude engraved on the chart, would appear as a straight line, giving a very erroneous impression as to which was the shortest route. This is owing to the principles on which a Mercator's Chart is projected, the meridians being parallel instead of converging. The difference between the "great circle" and the "rhumb" track is greatest when the course is nearly East and West, and in high latitudes.

The chief *theoretical* difficulty in "Great Circle" sailing, is the fact that the compass course *changes every instant*. That it must do so is evident, because the arc of a great circle drawn on a Globe, cuts each meridian (be they ever so near) at a different angle, and as the compass bearing is the angle between the meridian and the point indicated, this bearing must change at every Meridian; so that if we conceive a meridian at every 1′ of Longitude, the compass bearing changes at every 1′ of Longitude.

A vessel from the Cape (Table Bay) to Rio Janeiro, would, by the ordinary routine, steer W. by N. throughout, and make the distance 3,306 miles. Sailing on a "Great Circle," the distance would be 3,266 miles, but the course at first would be about W. ½ S. —in Long. 8° 31′ E. it would be due West—and at the end, about W.N.W. The theoretical difficulty of changing the ship's course every moment, is obviated practically, by finding (either by pointing the track on a Globe—or by Towson's Tables—or by computation) in what Latitude the Great Circle Track crosses a given Longitude, say 4° or 5° from the point of Departure, in the direction the ship is bound. Then, by Middle Latitude Sailing, compute the course between these two points. There will be no appreciable difference

so far, between a curve and a straight line. A *series* of Points, at every 5° of Longitude, may be found for the whole distance, and the track (apparently a curve towards the nearest Pole) laid down on the Mercator's Chart.

A 12-inch Globe, either Celestial or Terrestrial, will show a Great Circle track as near as most ships usually steer. *Any two* points representing the points of departure and arrival, being marked with paint (which will wash off), we can by lowering or elevating the brazen Meridian, get these two points to coincide with the wooden horizon. Then with a fine brush, paint a line just even with the horizon, joining the 2 points. The number of degrees between the 2 points, as shown on the wooden Horizon, gives the *Distance*, and the painted line the *Course*. By elevating the brazen meridian again, and marking at what latitude the successive meridians pass under it, we get a series of Points, from which the track may be laid down on the Mercator's Chart. It may also be observed (though not required except as a check on getting into too high a Latitude,) that when the points and track are lying even with the wooden horizon, the latitude shown by the brazen meridian, where it cuts the horizon, is the "*Latitude of the Vertex*," and the Longitude (on the Equator or Equinoctial line) cut by the brazen Meridian, is the "Longitude of the Vertex."

For Example. A vessel off Cape Clear (Ireland), in Lat. 51° 20′ N. and Long. 9° 30′ W., wishes to shape a Course for Cape Race (Newfoundland), in Lat. 46° 40′ N. and Long. 53° 00′ W. Mark these 2 points on the Globe; depress the N. Pole till these 2 points coincide with the wooden Horizon. Paint a fine red line from one point to the other, level with the Horizon. It will be found that Cape Clear is N. 5¼° E. and Cape Race N. 23¼° W., or a total Distance of 28½ degrees = 1,710 miles. It will also be seen that the horizon cuts the brazen Meridian at Lat. 51¾° N., which is the "Latitude of the Vertex," and that the brazen Meridian cuts the Equator (or Equinoctial) in Long. 19½° W., which is the "Longitude of the Vertex." Raise the brazen Meridian so as to get a good sight of the line of arc, or ship's track, and it will be found that at the successive Longitudes of 15°, 20°, 25°, 30°, 35°, 40°, 45°, 50° W. it will be cut in Latitudes 51½°, 51¾°, 51½°, 51¼°, 50¾°, 50°, 49°, 47½°.* These points can all be marked on an Outline or Track Chart, and a line

* The *correct* Points of the track will be shown in the *computed* Example, four pages on.

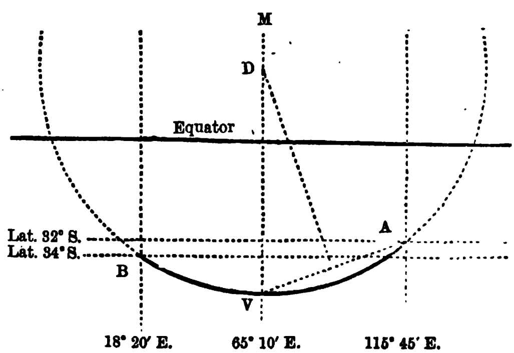
drawn through them, which will represent, near enough for most purposes, the Great Circle route.

N.B.—The "Course" for the first day's run may be deduced from the track in the usual way with the Parallel Ruler, or with a semicircular Protractor of paper, ½ an inch in diameter, which can easily be made and marked to ½ Points, so as to be read to ¼ Points by estimation. It will also suit for a 12-inch Globe. The more correct method of finding the Course will be given presently. If at the end of the first day's run, the ship is found to be much off the marked Track, a new one from the plan arrived at, must be laid down, rather than attempt to get back to the old track.

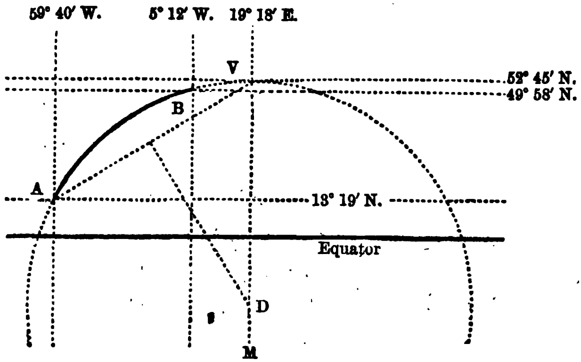
Great Circle Sailing is limited in practice, chiefly because it would often lead into such high Latitudes as to cause risk from icebergs. A vessel, for instance, from the Cape to Hobart Town, would have to go as far as 62° S., and the G. C. track from Cook's Straits, New Zealand, to Cape Horn leads into 66¾' S. In these cases, the extreme limit of Latitude is to be decided on before-hand, and a kind of *medium* curve adopted, which, though not so short as the Great Circle arc, is shorter than a Rhumb Course. This will be explained under the head of "Composite Sailing."

It may be useful to explain some of the terms used in Great Circle Sailing, and then to show the method of *computation*, when exactness is required.

It has already been stated that the shortest distance between any two places on the Earth's surface is that portion of a "great circle" which joins those places. This portion or arc, if continued on the surface of a Globe, will meet the Equator at two opposite points,



the Longitudes of which are 180° from each other; and the points on each semicircular arc, half-way between these two Longitudes, will be their *Vertices*, one in the N., the other in the S. hemisphere; *i.e.* these Vertices will be the places where each semicircle attains its highest Latitude. The Vertex, when the course is not far from East and West, will be somewhere "*on*" the arc joining the two places, as in the preceding figure, which represents the Great Circle course on a Mercator's Chart, from the Cape of Good Hope (B) to Swan River (A); or it may be "*out*" of the arc, *i.e.* on a prolongation of it, as in the following figure (this is always the



case when the latitude of the Vertex is found to exceed the latitude of either place), which represents the Great Circle track on a Mercator's Chart, from Barbadoes (A) to the Lizard (B).

To draw the Track on the Chart.

It is necessary first to obtain the latitude and longitude of the Vertex—either by computation (as shown farther on), or approximately by a Globe, or Towson's Tables. Draw on the Chart (as in the preceding figures) the Meridian of the Vertex VM. Join V and the place farthest from it, and bisect this line. From the point of bisection draw a perpendicular till it meets the Meridian of the Vertex at D. With D as a centre, describe the arc AB, which nearly represents the Great Circle track;* whence the interval points along the arc, whereby to get the *Course* to be steered can be taken out.

* This track will give rather too high latitudes about half-way between the Vertex, and the places sailed from and to.

N.B.—In practice, unless as a matter of interest the whole track is wanted for inspection on the Chart, it is unnecessary to find the Course except for the first day's run; because if at the close of that run, it is found that the vessel has deviated, say 30 miles from the track, it is better to lay down a fresh Great Circle track from the point reached, than to steer so as to rejoin the track left.

METHOD OF COMPUTATION.

Of the two places given, let B be always the one of greatest latitude, and A the one of least latitude. Let V be the Vertex.

The usual process is first to find the Distance; then the Latitude of the Vertex; then the Longitude of the Vertex; and lastly, a point on the Great Circle arc, about 5° of Longitude from the last place left, whereby to work the Course and Distance of one day's run by the usual Rhumb method. (Several of these points, at intervals of 5° of Longitude, may be found, if required to lay down the whole track. See N.B. preceding.)

To find the "Distance." *

I. $\text{Cos. } x = \sqrt{(\text{sin. } \tfrac{1}{2} \text{ diff. long.})^2 \times \text{cos. lat. A} \times \text{cos. lat. B.}}$

II. $\text{Cos. } \tfrac{1}{2} \text{ Distance} = \sqrt{\text{sin. } (x + \tfrac{1}{2} \text{ diff. lat.}) \times \text{sin. } (x - \tfrac{1}{2} \text{ diff. lat.})}$

Example. A vessel off Cape Clear, in 51° 20′ N. lat. and 9° 30′ W. long., requires her Great Circle Distance to a point just off Cape Race (*en route* to New York), in 46° 40′ N. lat., and 53° 00′ W. long.

---

* Or the "Distance" may thus be found, as a check on the other.

I. $y = \sqrt{(\text{sin. } \tfrac{1}{2} \text{ diff. long.})^2 \times \text{cos. lat. A} \times \text{cos. lat. B.}}$

II. $\text{tan. arc. 1st.} = y \div \text{sin. } \tfrac{1}{2} \text{ diff. lat.}$

III. $\text{Sin. } \tfrac{1}{2} \text{ Distance} = y \div \text{sin. Arc 1st.}$

LATS.		LONGS.	
Cape Clear = B =	51° 20′ N.	Cape Clear B =	9° 30′ W.
Cape Race A =	46 40 N.	Cape Race A =	53 00 W.
	2) 4 40		2)43 30
½ diff. Lat.	2 20	½ diff. Long.	21 45

½ diff. long. = 21° 45′ sin.	9·568855
	2
	19·137710
Lat. A = 46° 40′ cos.	9·836477
Lat. B = 51 20 cos.	9·795733
	2)18·769920
x = 75° 57½′ cos.	9·384960
½ diff. Lat. = 2 20	
Sum = 78 17½ sin.	9·990868
Diff. = 73 37½ sin.	9·982016
	2)19·972884
½ Distance 14° 14½′ cos.	9·986442
Distance 28° 29′ = 1709 miles.	

To find "Latitude" of Vertex.

$$\text{Cos. lat. V} = \frac{\text{cos. lat. A} \times \text{cos. lat. B} \times \text{sin. diff. Long.}}{\text{sin. Distance.}}$$

Lat. A = 46° 40′ cos.	9·836477
Lat. B = 51 20 cos.	9·795733
Diff. Long. = 43 30 sin.	9·837812
	29·470022
Distances = 28° 29′ sin.	9·678430
Lat. of V. 51° 46′ N. cos.	9·791592

Here, as Lat. V exceeds both Lat. A and Lat. B, the Vertex is "in" the arc.

To find "Longitude" of Vertex.

(I) Cos. m = tan. Lat. A × cotan. Lat. V.

(II) $m \sim$ Long. A = Longitude of Vertex.

N.B.—*m* is the diff. Long. between the Meridian of V, and the Meridian of A (it is sometimes called "the Meridian *from* the Vertex); and is East of A, if B is East of A; and *vice versâ*.

Lat. of A = 46° 40′	tan.	10·025281	
Lat. of V = 51° 48″	cot.	9·896452	
m = 33° 22½′	cos.	9·921733	(Here m is East)
Long. A = 53 00 W.			
Longitude of V = 19 37½ W.			

To find one, or a succession of Points on the Arc.

Let d = diff. long. between the Meridian of the Vertex, and the Meridian of any point P, on the Arc. Then for the latitude of P

Tan. Lat. P = cos. d × tan. Lat. Vertex.

In the above Example, a steamer *leaving Cape Clear* may be expected to make about 8° of Longitude in the day's run, or what will bring her to Long. 17° 30′ W. Required the Latitude of this Point.

Longitude of Vertex = 19° 37·5′ W.			
Longitude of P = 17 30 W.			
d = 2 7·5	cos.		9·999700
Latitude of Vertex = 51° 46′	tan.	+	10·103548
Latitude of P = 51° 45′	tan.		10·103248

Having, then, the position whence the vessel starts, and the position of P on the arc, the Course and Distance are computed by Middle Latitude, or by Mercator = N 85° 13′ W. 300 miles.

In this way a *succession* of Points the whole way along the Arc, at intervals, say of 5° of Longitude, may be computed, when it is an object to lay down the entire track on the Chart,* (but see N.B. page 90). The track would be as follows:

LONGITUDES.	9° 30′ W.	15° 00′ W.	19° 37′ W.	25° 00′ W.	30° 00′ W.
LATITUDES.	51 20 N.	51 41 N.	51 46 N.	51 39 N.	51 18 N.

* To show how near the chords between the intermediate points on the track approximate to the true arc, refer to Case IV. page 96. Using only 7 of the points there calculated, at distances of about 20° of Longitude, the sum of the Distances by Rhumb = 4696½ miles, or only 8½ miles more than the computed distance on the Great Circle. In Case VII., where each chord is 5° of Longitude, and very carefully computed (in "Kerrigan's Navigation"), the total is 6109 miles, the true arc being 6108 miles.

LONGITUDES.	35° 00′ W.	40° 00′ W.	45° 00′ W.	50° 00′ W.	53° 00′ W.
LATITUDES.	50 45 N.	49 57 N.	48 55 N.	47 36 N.	46 40 N.

The whole Course* and Distance by Rhumb is S 81° 22′ W., 1732 miles.

The Distance by Great Circle sailing is 1709 miles, or 23 miles shorter.

If in the previous Example the vessel is supposed to be *leaving Cape Race*, and it is required to find the Latitude of a place on the Arc in Longitude 46° 10′ W. (about a day's steam), we have

Longitude of Vertex	19° 37½′ W.		
Longitude of V	46 10 W.		
d =	26 32½	cos.	9·951634
Latitude of Vertex =	51 46	tan. +	10·103548
Latitude of P =	48 38	tan.	10·055182

From this, the Course and Distance from the given position off Cape Race, is computed by Mercator, or by Mid. Lat. sailing = N. 66° 52′ E. 300 miles.†

N.B.—1st. When the two given Places are on the same parallel of Latitude, the computation is simplified. In the first place, the Longitude of the Vertex is known at once, being exactly *half-way* between the two given Longitudes; and in the second place, in working the "Distance," the logarithm that usually represents the *cosine* of x (as 9·384960 in the Example, page 91,) represents the *sine* of ½ the Distance. This might be exemplified in Case III., page 96. For Lat. vertex, see also, Case III., p. 96.

N.B.—2d. In all cases where the two places are at all near East and West of each other (*i.e.* in cases where the Vertex lies well within the arc forming the places), it is unnecessary in drawing the whole track on the Chart, to compute the Points on both sides the Vertex. Begin at the Place (A) of least Latitude, and compute for every 5° or so of Long. as far as the Vertex, and then the points on

* Some remarks upon the "Course" on the Great Circle arc, will be offered towards the close of this Article.

† In this case, as in the day's run from Cape Clear, the Distance comes out 300 miles in both instances; but this is accidental. It is usual to take about 5° degrees of Longitude as made in a day, or 7° in high latitudes.

the *other* side of the Vertex, equidistant in Longitude from the Meridian of the Vertex, will have the same Latitudes as those already computed. Thus, if the Meridian of the Vertex is 27° E., and the Latitude of a point in 10° E. has been found to be 41° 48′ S., the Latitude of a point in Lat. 44° E. will be also 41° 48′ S. (See Case II., page 95.)

N.B.—3d. If the Latitude of the Vertex is known, we can find the Distance thus:

$$\text{Sin. Distance} = \frac{\text{cos. Lat. A} \times \text{cos. Lat. B} \times \text{sin. diff. Long.}}{\text{cos. Lat. Vertex.}}$$

N.B.—4th. If, when the Lat. and Long. of the Vertex are known, a certain parallel of Latitude is given, and we want to know in what longitude it will be crossed, we first find d or the degrees of Longitude *from the Vertex*, thus: $\cos. d = \frac{\text{Tan. of given Lat.}}{\text{Tan. of Lat. of Vertex}}$. Then $d +$ Long. of Vertex, and $d -$ Long. of Vertex, will be the Longitudes in which the arc cuts the given Parallel of Latitude.

N.B.—5th. Another formula for finding the Longitude of the Vertex, without finding the Distance, is as follows:

$$\left.\begin{array}{l} S = \text{sum of Latitudes} \\ D = \text{diff. of Latitudes} \\ L = \tfrac{1}{2}\text{ diff. Long.} \\ M = \tfrac{1}{2}\text{ way Meridian} \end{array}\right\} \begin{array}{l} \text{Tan } x \dfrac{\sin D \times \cot L}{\sin S} \ (x \text{ being E. if B is East of A}) \\ \text{Long. V} = \begin{cases} x + \text{M, if both E. or both W.} \\ x \sim \text{M, if one E. and the other W.; Long. V being of same name as the greater.} \end{cases} \end{array}$$

M = ½ *sum* of the Longitudes, when both E. or both W.; but M = ½ *diff.* of the Longitudes if one E. and the other W.; M being of the same name as the greater. *Example.* From Rio Janeiro to Table Bay (see No. 5 of the List in page 97).

D = 10° 58′	sin.	9·279297
L = 30 46	cot.	0·225241
		9·504538
S = 56 48	sin. —	9·922603
x = 20 54 E.	tan.	9·581935
M = 12 23 W.		
Long. of V = 8 31 E.		

[When the Longitude of one of the places is near 180° E., it is better to turn it into W. Longitude, as in the route from off Cape Palliser (N. Zealand) to Cape Horn, page 103. The Long. of A (Cape P.) is 175° 18′ E., which = 184° 42′ W. Then

$$\frac{184° 42' \text{ W.} + 67° 16' \text{ W.}}{2} = 125° 59' \text{ W.} = \text{M.}]$$

The above method of finding the Longitude of the Vertex is a *good check* on the usual method. When found, the *Latitude* of the Vertex may be thus computed. Let d = diff. Long. between A (the place of least latitude) and the Vertex. Then

$$\text{Cot. Lat. V} = \cos. d \times \text{cotangent lat. A.}$$

Thus in the above case, $d = 43° 9' + 8° 31' = 51° 40'$

d =	51° 40′	cos. 9·792557
Lat. A =	22 55	cot. 0·373907
Lat. of Vertex =	34 16¾	cot. 0·166464

(When A and B have the same latitude, d always = ½ diff. Long.)

Besides the case given in page 90, the following may be tracked out on the Chart as useful; though the two last, as leading into too high a latitude, will again be referred to, with others, under "Composite sailing."

I. *St. Thomas's to the Lizard*, or from 18° 20′ N., 64° 54′ W., to 49° 54′ N., 5° 12′ W. Distance 3402 miles. Vertex in Lat. 50° 50′ S.; Long. 9° 26′ E. Course and Distance by Rhumb = N. 56° 47′, E. 3457 miles, or 55 in excess.

LONG.	64° 54′ W.	60° 00′	55° 00′	50° 00′	45° 00′	40° 00′	35° 00′
LATS.	18 20 N.	23 19	27 54	31 58	35 31	38 56	41 14
LONG.	30 00 W.	25 00	20 00	15 00	10 00	5 12	
LATS.	43 28 N.	45 21	46 54	48 10	49 10	49 54	

The arc, if continued, would reach to the Vertex above given, cutting Longitudes 0° 0′ and 5° 0′ E., in Lats. 50° 27′ and 50° 45′.

II. *An Outward-bound Indiaman*, not to touch at the Cape, after leaving the S.E. Trade, is in Lat. 27° S., and Long. 30° W., and wishes to get into the place for the other S.E. Trade, in 32° S., and

Long. 75° E. The Distance is 5245 miles. Vertex in Lat. 43° 4′ S.; Long. 26° 58′ E. (The direct Course by Rhumb is impracticable.)

LONG.	30° 00′ W.	25° 00′	20° 00′	15° 00′	10° 00′	5° 00′	0° 00′	5° 00′ E.
LATS.	27 00 S.	29 58	32 32	34 48	36 45	38 25	39 48	40 55
LONG.	10 00 W.	15 00	20 00	25 00	30 00	35 00	40 00	45 00
LATS.	41 48 S.	42 26	42 51	43 3	43 2	42 47	42 19	41 38
LONG.	50 00 W.	55 00	60 00	65 00	70 00	75 00		
LATS.	40 46 S.	39 31	38 5	36 22	34 21	32 00		

If this arc is extended Easterly to the same latitude it started from (viz. 27°), it will reach to Long. 83° 56′ E., cutting Longitude 80° in 29° 20′ S. It may be continued to 90° E. of Vertex, which reaches the Equator in 116° 58′ E., cutting Longitudes 90°, 100°, 104°, 110°, 115°, in Lats. 22° 58′, 15° 15′, 11° 51′, 6° 28′, and 1° 50′ S.

III. *Another* useful track, somewhat similar to the preceding, is from Lat. 30° S., Long 19° W., to Lat. 30° S., Long. 79° E. (The latitudes being the same, the *Long.* of the Vertex is just ½ way, or 30° E.; and Cot. *Lat.* of Vertex = cos. ½ diff. Long. ÷ tan. Lat. A (or B), as at the end of N.B. 1st, page 93) = 41° 21′ S.

LONG.	19° 00′ W.	15° 00′	10° 00′	5° 00′	0° 00′	5° 00′ E.	10° 00′
LATS.	30 00	31 54	33 59	35 47	37 19	38 54	39 35
LONG.	15 00	20 00	25 00	30 00	35 00	40 00	45 00
LATS.	40 22	40 55	41 15	41 21	41 15	40 55	40 22
LONG.	50 00	55 00	60 00	65 00	70 00	75 00	79 00
LATS.	39 35	38 34	37 19	35 47	33 59	31 54	30 00

IV. *From the Cape of Good Hope to Swan River*, or from 34° 0′ S., 18° 20′ E., to 32° 3′ S., 115° 45′ E. Distance 4687 miles. Vertex in Lat. 44° 35½′ S., and 65° 10′ E. By Rhumb, the Course and Distance is N. 88° 38′ E. 4906 miles; or 219 miles in excess.

LONG.	18° 20′ E.	21° 00′	25° 00′	30° 00′	35° 00′	40° 00′	45° 00′
LATS.	34 00 S.	35 16	37 00	38 52	40 26	41 44	42 47
LONG.	50 00	55 00	60 00	65 10	70 00	75 00	80 00
LATS.	43 35	44 8	44 29	44 36	44 29	44 10	43 37
LONG.	85 00	90 00	95 00	100 00	105 00	100 10	115 45
LATS.	42 58	41 49	40 32	38 59	37 8	35 16	32 3

This Example is given in Riddle's Navigation." (See foot-note, page 92.)

V. *Rio Janeiro to Table Bay*, or from Lat. 22° 55′ S.; Long. 43° 9′ W., to Lat. 33° 53′ S.; Long. 18° 23′ E. Distance 3266 miles. Vertex in Lat. 34° 17′ S., Long. 8° 31′ E. Course and Distance by Rhumb, S. 78° 31½′ E. 3306 miles; or 40 miles in excess.

Long.	43° 9′ W.	40° 00′	35° 00′	30° 00′	25° 00′	20° 00′	15° 00′
Lats.	22 55 S.	24 18	26 18	28 4	29 36	30 42	32 00
Long.	10 00 W.	5 00	0 00	5 0 E.	15 00	18 23	
Lats.	32 53	33 52	33 59	34 14	34 7	33 53	

VI. *Cape to Bass's Straits*, or from Lat. 34° 22′ S.; Long. 18° 26′ E., to Lat. 39° 30′ S.; Long. 143° 56′ E. Distance 5437 miles. Vertex in Lat. 58° 46′ S.; 83° 56′ E. Course and Distance by Rhumb S. 87° 4′ E. 6024 miles; or 587 miles in excess.

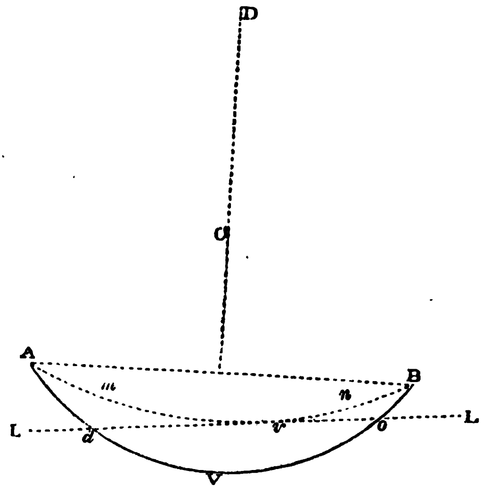
Long.	18° 26′ E.	23° 56′	30° 00′	35° 00′	40° 00′	45° 00′	50° 00′
Lats.	34 22	39 30	44 9	47 17	49 54	52 3	53 50
Long.	55 00 E.	60 00	65 00	70 00	75 00	80 00	85 56
Lats.	55 17	56 26	57 20	58 00	58 27	58 42	58 46
Long.	87 52 E.	92 52	97 52	102 52	107 52	112 52	117 52
Lats.	58 42	58 27	58 00	57 20	56 26	55 17	53 50
Long.	122 52 E.	127 52	132 52	137 52	143 56		
Lats.	52 3	49 54	47 17	44 9	39 30		

VII. *Port Jackson to Valparaiso*, or from Lat. 33° 52′ S.; Long. 151° 16′ E., to Lat. 33° 1′ S.; Long. 71° 52′ W. Distance 6108 miles. Vertex in Lat. 60° 54′ S., and Long. 140° 40′ W. Course and Distance by Rhumb, N. 89° 34′ E. 6853 miles; or 745 miles in excess.

Long.	151° 16′ E.	156° 16′	161° 16′	166° 16′	171° 16′	176° 16′
Lats.	33 52 S.	39 8	43 33	47 12	50 13	52 42
Long.	178 44 W.	173 44	168 44	163 44	153 44	140 40
Lats.	54 45 S.	56 25	57 46	58 50	60 16	60 54
Long.	128 44 W.	113 44	108 44	103 44	98 44	93 44
Lats.	60 22 S.	58 2	56 45	55 9	53 12	50 49
Long.	88 44 W.	83 44	78 44	73 44	71 52	
Lats.	47 56 S.	44 26	40 13	35 9	33 1	

"COMPOSITE" GREAT CIRCLE SAILING.

Though sailing on a *true* Great Circle cannot be carried out practically with more than 3 or 4 per cent. advantage in distance, over Rhumb sailing (owing to its reaching into too high latitudes), there is an *intermediate* method, which, though not on a true Great Circle arc, may yet in some instances gain 9 or 10 per cent. on the distance by Rhumb sailing. *Practically*, therefore, this "Composite" sailing is of more importance than *true* Great Circle Sailing.



Let the figure represent two places A and B. The true Great Circle track as shown on a Mercator's Chart, would be A, *a*, V, *o*, B; but if it is determined not to go to a higher latitude than L, the following is the *usual* method. Find the Lat. and Longitude of the Vertex V (either by calculation, or Towson's tables approximately), and calculate the Longitudes of *a* and *o** (or where the arc of the

---

* The Formula is as follows:

Let P be the point whose Longitude is required; and d = diff. Long. between P and the meridian of the Vertex. Then

$$\cos. d = \tan. \text{ given Latitude} \div \tan. \text{ Lat. of Vertex.}$$

From this we find a and o, being d + Long. of Vertex, and $d \sim$ Long. of Vertex.

Great Circle cuts the given parallel). Then steer to *a*, and run down the longitude *a o* on the given parallel, and from *o* on the Great Circle arc to B. This does not require any diagram to be drawn on a chart; but there is *another* method of "Composite" sailing, described by the Rev. G. Fisher, in Riddle's Navigation, which is a great improvement on the *usual* method, both as regards distance, and time spent in very high latitudes. It requires a chart, but an outline one of 15° to 1 inch, and only between the parallels of 30° and 60°, such as is given at the end of this paper is sufficient, if carefully drawn. Join A B, and bisect the line. From the point of bisection raise a perpendicular in the direction of D; and on this line, find a place (by trial) where, if one point of a pair of compasses is placed, the other point will not only touch both A and B, but also just graze the parallel of Latitude determined on (which in the figure it does at *v*). Along this Composite track A *m v n* B, dot off points at intervals of 5°, or even 10° of Longitude. Write down the Latitude and Longitude of each point, as taken from the chart, and compute the Course and Distance between each, by Mercator or by Middle latitude sailing; or it will be sufficient to calculate the Course and Distance for what may do for one day's run only; as, if the ship gets off the track, it is better to draw a new one.

In the preceding figure, the line A*mvn*B will nearly represent the Composite track by Fisher's method from the Cape to Hobart Town; or from Lat. 34° 22′ S., and Long. 18° 26′ E.; to Lat. 42° 54′ S. and Long. 147° 26′ E.; the maximum Latitude being 50° S. Mr. Fisher, with a Chart of 18° of Longitude to 1 inch, and intervals of 10° of Longitude, makes it 5579 miles. With a Chart on the same scale, but very carefully drawn,* and 5° intervals (the Vertex was in 93° 45′ E.), the distance came out 5577 miles. With an ordinary outline Chart, on a scale of 6° to 1 inch, and 5° intervals, it came out 5581 miles. By Spherical Trigonometry, with the method shown in page 90, the Distance, on the arc of the Great Circle going to 61° 58′ S. is 5387 miles. The distance by Rhumb is 6052 miles; so that this Composite track *saves* 475 *miles on the Rhumb*, though itself 190 miles more than the *true* Great Circle track.

---

* A chart on a small scale has this advantage, that the arc can be described with an ordinary pair of compasses and lengthening bar. A large Chart requires beam compasses. See the end of this article, as to the matter of charts.

The following will exhibit the respective Latitudes and Longitudes on the small chart, of the Composite track by Mr. Fisher's method.

S. Lat.	E. Long.	Courses.	Dist.	
° ′	° ′	° ′		
34 22	18 26			
38 00	25 00	S. 55 33½ E.	385·6	From A to lat. of B 1121·9.
40 00	30 00	„ 62 46 „	262·2	
41 30	35 00	„ 68 24 „	244·5	
43 00	40 00	„ 67 56 „	239·6	
44 20	45 00	„ 69 45¾ „	231·3	2222·5
45 30	50 00	„ 71 54 „	225·3	
46 30	55 00	„ 73 56 „	216·8	
47 20	60 00	„ 76 17½ „	211·0	
48 00	65 00	„ 78 48 „	205·9	
48 40	70 00	„ 78 39¼ „	203·3	
49 10	75 00	„ 81 21½ „	199·6	
49 30	80 00	„ 84 9½ „	196·5	
49 45	85 00	„ 85 34¾ „	194·5	
49 55	90 00	„ 87 2½ „	193·8	
50 00	93 45	„ 88 1 „	144·5	
		From A to Vertex =	3354·4	
		From Vertex to B =	2222·5	
		Total =	5576·9	

When once the places from A to the Vertex have been taken out, and Courses and Distances computed, the track from the Vertex to B is as good as given: for Longitudes at equal distances each side of the Vertex, have the same Latitudes.

Now, to compare the distance by *this* Composite, with that by the *usual* method of Composite Great Circle Sailing. It is evident, by reference to the figure, that the distance by the *usual* Composite method (A, *a*, *v*, *o*, B), exceeds the true Great Circle arc, as the distance *a*, *o*, by Parallel sailing, exceeds the Creat Circle arc *a*, V, *o*. We have then first to find the Longitudes in which *a* and *o* are situated,* which in the above Example, are 36° 28′ E., and 137° 42′ E.;

* As shown in the foot-note, 3 pages back.

Given Lat. =	50° 00′	tan.	0·076186
Lat. of V =	61 58	tan. —	0.273716
d =	50 37 E.	cos.	9.802470
Long. V =	87 5 E.		
Diff. =	36 28 E. = *a*		
Sum. =	137 42 E. = *o*		
Diff. Long. =	101 14	or twice *d*.	

the distance a, v, o being 101° 14′ of Longitude, which in the parallel of 50° = 3904 miles. The Great Circle arc a, V, o is calculated (as shown 8 pages further back) 3575 miles.* The excess therefore by Parallel sailing this portion, is 329 miles. The entire Great Circle distance from A to B is 5387 miles; and hence the distance by the *usual* Composite is 5387 + 329 = 5716 miles; whilst, as just shown, the distance by *Mr. Fisher's method* is 5577 miles, or a gain of 139 miles on the usual method, with the advantage (not an inconsiderable one) of having much less distance to run in an iceberg latitude.

Take another Example. A vessel coming out of Bass's Straits, bound round Cape Horn; or from 40° 30′ S., and 148° 0′ E., to 56° 10′ S., and 67° 10′ W. By true Great Circle sailing, the Distance would be 4730 miles, and the Vertex in 75° 34½′ S., and 134° 41¾′ W. The parallel of 60° S., supposing this to be fixed as the maximum Latitude, would be crossed in Longitudes 161° 46′ E., and 71° 9′ W.; giving 127° 4′ of Parallel sailing = 3812 miles, or 621 miles more than the arc of the Great Circle between the above Longitudes; making a *total* distance of 5351 miles. But by Mr. Fisher's method (the track of which is given in the margin), the distance is 5151 miles, or 200 miles gained.

Longs.	Lats.	Dist.	
° ′	° ′		
148 00 E.	40 30 S.		
155 00 ,,	44 15 ,,	383·1	2128·3
165 00 ,,	48 20 ,,	481·3	
175 00 ,,	51 30 ,,	430·4	
175 00 W.	54 00 ,,	392·8	
162 44 ,,	56 10 ,,	440·7	
155 00 ,,	57 30 ,,	266·1	1511·4
145 00 ,,	58 30 ,,	323·7	
135 00 ,,	59 10 ,,	313·0	
125 00 ,,	59 40 ,,	306·5	
115 00 ,,	60 00 ,,	302·1	

From B. Sts. to Vertex = 3639·7
From Vertex to C. Horn = 1511·4
Total 5151·1

(The places in the margin were taken from a Chart similar to that at the end of this paper, and gave a vertex in Long. 115° 0′ W.)

---

* Lat. of Parallel =	50°	cos.		9·308067
				2
				19·616134
Diff. Long. =	101° 14′	sin.	+	9·991599
				29·607733
Lat. V =	61 58	cos.	—	9·672084
Distance	59 34¼	sin.		9·935649

Again, a vessel coming out of Cook's Straits (N. Zealand), bound round Cape Horn; or from 42° 10′ S., and 175° 18′ E., to 56° 10′ S., and 67° 16′ W. By true Great Circle sailing the Distance would be 4106 miles, and the Vertex in 66° 48½′ S., and 117° 32′ W. The parallel of 57° S., supposing this to be fixed as the maximum

Long.		Lat.		Dist.
°	′	°	′	
175	18 E.	42	10 S.	
175	00 W.	45	15 ,,	457·3
165	00 ,,	48	4 ,,	447·2
155	00 ,,	50	40 ,,	420·6
145	00 ,,	52	30 ,,	388·6
135	00 ,,	54	00 ,,	270·1
125	00 ,,	55	15 ,,	355·4
115	00 ,,	56	6 ,,	342·2
105	00 ,,	56	30 ,,	333·6
95	00 ,,	56	45 ,,	330·1
87	00 ,,	57	00 ,,	262·6
From C. Sts. to Vertex =				3707·8
87	0 W.	57	00 ,,	
79	0 ,,	56	45 ,,	262·6
69	0 ,,	56	30 ,,	330·1
67	16 ,,	56	10 ,,	61·0
From Vertex to C. Horn =				653·7
			Total	4361·5

Latitude, would be crossed in Longitudes 166° 15¼′ W., and 68° 48¾′ W., giving 97° 26½′ of Parallel Sailing, = 3184 miles, or 284 more than the arc of the Great Circle between the above Longitudes; making a *total* distance of 4490 miles. But by Mr. Fisher's method, the track of which is given above, the distance is 4361 miles, or 200 miles gained, with much less high latitude sailing. The places in the Table were taken from a Chart similar to that at the end of this paper, and gave a Vertex in Longitude 87° 0′ W.

If the maximum Latitude fixed upon, does not differ much from that reached by the Great Circle arc, there will not be so much difference between the *usual* Composite, and Mr. Fisher's method. For

example, a vessel from Port Jackson to Valparaiso, as given in Case VII., page 97. If the object is just to clear the S. end of New Zealand, the curve by Mr. Fisher's method, as shown in the Chart at the end of this paper, will go to $58\frac{1}{4}°$ S. The Distance is 6143

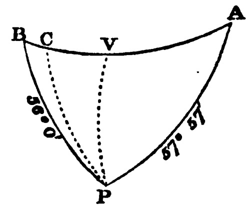
Long.	Lat.	Dist.
° ′	° ′	
151 16 E.	33 52 S.	
155 00 ,,	38 50 ,,	348·3
160 00 ,,	42 50 ,,	330·3
165 00 ,,	46 5 ,,	289·6
170 00 ,,	48 45 ,,	258·4
175 00 ,,	50 55 ,,	233·1
180 00 ,,	52 40 ,,	213·2
175 00 W.	54 10 ,,	200·2
170 00 ,,	55 25 ,,	188·5
165 00 ,,	56 25 ,,	178·5
160 00 ,,	57 10 ,,	170·4
155 00 ,,	57 40 ,,	164·3
150 00 ,,	58 00 ,,	160·9
145 00 ,,	58 10 ,,	158·9
141 00 ,,	58 15 ,,	126·5
From P. J. to Vertex =		3021·1
From Vert. to Lat. 33° 52′ and 73° 16′ W.		3021·1
To Valparaiso		100·7
Total		6142·9

miles, and the track will be, as shown in the margin; the Distance being 6143 miles, or only 7 less than the *usual* Composite route, which would cross the parallel of 58° 15′ S., in Longitudes 114° 45′ W., and 166° 35′ W. (The distance on this parallel is $1636\frac{1}{4}$ miles by Parallel Sailing, and $1595\frac{1}{2}$ by Great Circle Sailing.)

The Great Circle "Course."

It has been observed before, that *theoretically* speaking, the Course should be changed every instant; but *practically*, the Course is calculated for 300 miles or so in advance, by Rhumb sailing, and if the ship makes good what is expected, the Rhumb line will not appreciably differ from the Great Circle arc.

However, if it really is required to know the angle of Course at the *very commencement* (and practically it will hold good for 200 miles or so), it must be calculated by Spherical Trigonometry. In the accompanying figure (which applies to Case IV., page 96), let B represent the Cape, and A Swan River. Then P will be the Pole, BA will be the Distance, and the sides BP, AP, the Co-latitudes of B and A. These sides represent the Meridians of the Earth; and the 'angles of Position' at B and A, represent each the angle between the Meridian, and the ship's track, or in other words the "Course." It is seen at once that a vessel from B changes this angle every moment, as when she reaches C, the angle (or Course) will be greater than at B, and when she reaches V or the vertex, the angle AVP becomes a right angle, and the course is for the moment due East. (Using cos. Lat. for sin. Colat., we have)



$$\text{Sin.} \angle A = \frac{\text{Sin. Diff. Long.}}{\text{Sin. Distance}} \times \text{Cosin. Lat. B.}$$

$$\text{Sin.} \angle B = \frac{\text{Sin. Diff. Long.}}{\text{Sin. Distance}} \times \text{Cosin. Lat. A.}$$

N.B. The angle at the place of greatest Latitude, is always greater than the other.

The above Formula is so far convenient, that with it we can find the value of one angle, without having to find both. This is not the case with the following Formula, which, however, has the advantage of being independent of the *Distance;* for any error in the Distance

affects the "angles of position." (x is $\frac{1}{2}$ the sum, and y $\frac{1}{2}$ the diff. the angles.)

$$\text{Tan. } x = \frac{\text{Cos. } \frac{1}{2} \text{ diff. Lat.}}{\text{Sin. } \frac{1}{2} \text{ sum Lats.}} \times \text{Cot. } \tfrac{1}{2} \text{ diff. Long.}$$

$$\text{Tan. } y = \frac{\text{Sin. } \frac{1}{2} \text{ diff. Lat.}}{\text{Cos. } \frac{1}{2} \text{ sum of Lats.}} \times \text{Cot. } \tfrac{1}{2} \text{ diff. Long.}$$

Then $x + y$ = Greater angle (always at place of greatest Latitude).

$x - y$ = Lesser angle (always at place of least Latitude).

Taking the Example in pages 90, 91; Required the Great Circle "Initial Course" from off Cape Race to off Cape Clear, and also that from Cape Clear towards Cape Race; or at A and at B.

By Formula I.

Diff. Long. =	43° 30′	sin.	9·837812			
Distance =	28 29	sin. —	9.678430			
			0·159382	. . . .		0.159382
Lat. B =	51 20	cos. +	9·795733	Lat. A =	46° 40′	cos. 9·836477
Angle at A =	N 64 24 E.	sin.	9·955115	Ang. at B =	N 82 6 W.	sin. 9·995859

By Formula II.

½ diff. Lat. =	2° 20′	cos.	9·999640	. . . . sin.	8·609734
½ sum Lats. =	49 0	sin. —	9·877780	cos. —	9·816943
			0·121860		8·792791
½ diff. Long. =	21 45	cot. +	0·399071		0·399071
x =	73 13¾	tan.	0·520931	y = 8° 50½′ tan.	9·191862
y =	8 50½				
Sum =	82 4¼ at B				
Diff. =	64 23¼ at A				

The slight difference in the result is owing to a slight error in the "Distance," affecting Formula I.

Take again the Great Circle track from the Cape to Swan River as given in Case IV. p. 96.

By Formula I.

Diff. Long. 97° 25′	sin.	9·296351		
Distance 78 7	sin. —	9·990591		
		0·005761	. . . .	0·005761
Lat. A = 32° 3′	cos. +	9 928183	Lat. B = 34° 0′ cos.	9 918574
Angle at B = S. 59 11½ E.	sin.	9·933943	Ang. A = S. 57° 9′ W. sin.	9·924334

By Formula II.

½ diff. Lat. = 0° 58½′	cos.	9·999937	. . . . sin.	8·230861
½ sum. Lats. = 33° 1½′	sin. —	9·736400		9·923386
		0·263537		8·3 ·7475
½ diff. Long. = 48° 42½′	cot. +	9·943625		9·943625
x = 58 10½	tan.	0.207162	y = 1° 1½′ tan.	8·251100
y = 1 1½				
Sum. 59 11¾ angle at B				
Diff. 57 9¼ angle at A				

It will be found that a vessel sailing 300 miles in the 24 hours, *exactly* on the "Initial Course," would, at the end of that time, be some 10 or 12 miles out of the Great Circle track, and that it would be better to shape her course *larger* than the "Initial Course," by about 2°, for the above distance. Practically, no vessel could be sure of steering to 1°, but it may be as well to exemplify the above statements; and it may be incidentally observed, that these *angles*, and the *distance*, require to be very accurately taken out, in finding the Latitude by double altitudes of the Sun, or by the simultaneous altitudes of two Stars. In these cases we have Right Ascensions instead of Longitudes, and Declinations instead of Latitudes.

A vessel off Cape Race, bound to Cape Clear (taking the Latitudes and Longitudes given in preceding pages), if she steered N. 66° 52′ E., for 300 miles, would reach Latitude 48° 38′ N., and Longitude 46° 10′ W., a point exactly on the Great Circle track; whereas, had she sailed 300 miles on the "Initial Course," N. 64° 23½′ E., she would have found herself in Lat. 48° 49¾′ N., and Longitude 46° 17½′ W.; being out of the Great Circle track 12 miles of Lat. and 7½′ of Long. Again, from off Cape Clear, if she sailed 300 miles N. 85° 13′ W., she would reach Lat. 51° 45′ N., and Long 17° 30′ N., a place exactly on the Great Circle track; whereas, with the "Initial Course,"

82° 4¼′, she would be in Lat. 52° 1½′ N., and Long. 17° 29¼′ W., or off the track 16½ miles of Lat., and 1′ of Long.

In Case VII., eleven pages back, from the Cape to Swan River, the "Initial Course" is S. 59° 11¾′ E. This, after 300 miles, would bring the vessel to Lat. 36° 34′ S., and Long. 23° 36′ E. (which is off the track); whereas, a Course of S. 60° 49′ E., for 300 miles, would bring her to Lat. 36° 26′ S., and Long. 23° 40′ E., a place exactly on the Great Circle track.

Again, in Case VI., ten pages back, the "Initial Course" is S. 55° 5′ W., from the place of least Latitude. This, after 300 miles, would bring the ship to Lat. 29° 52′ S., and Long. 25° 20′ W., which is off the Great Circle track. Had the vessel sailed the 300 miles on a S. 56° 14′ E. Course, she would have been exactly on the track, in 29° 47′ S., and 25° 16′ W.

Again, in Case VII., ten pages back, the "Initial Course" at each end (for the latitudes are the same) is 60° 5½′. This, from the place farthest to the Westward, would, at the end of 300 miles, place the ship in Lat. 32° 29′ S., and Long. 13° 56′ W., which is off the Great Circle track. Had the vessel sailed the 300 miles on a S. 61° 28′ E. Course, she would have been exactly on the track, in 32° 24′ S., and 13° 51′ W.

Mr. Saxby's "Spherograph"* will be found useful in practice, for taking out the "Course" between the ship's present place and any other to which she is bound. It is a mere matter of *inspection*, not requiring any knowledge of the "Vertex," or use of scales and dividers. It gives the "Initial Course," and therefore, *theoretically*, is only good for the moment; but *practically*, as has been shown, by increasing the "Initial Course" about 2°, a run of 300 miles will find the vessel almost *exactly* on the true Great Circle track. This ingenious instrument, however, does not give the requisite data for "Composite" Great Circle Sailing, which, after all, is of more consequence than "True" Great Circle sailing, for the latter cannot be carried out in those high latitudes, where it would be most effective in shortening the Distance.

Towson's Tables also are useful for ascertaining (*approximately*) the Vertex, and thence the Distance, and the "Initial Course."

---

* See the Articles "Spherograph" and "Great Circle Sailing," in Knight's English Encyclopædia [Arts and Sciences].

On the construction of a Chart.

A blank Mercator's Chart, between the parallels of 30° and 60° (which will do for either N. or S. Latitude), and embracing 150° of Longitude (which will do for either Hemisphere), will be found useful in laying down the 'Composite' Great Circle track, either by the *usual*, or by Mr. Fisher's method. The scale of 15°, (or 900′) of Longitude, to 1 inch, will, if carefully constructed, fully answer the purpose. Such a map is shown in the Plate p. 110.

For the above Scale, the following Table is applicable, and will enable any one to construct the Chart. The horizontal line of Longitude, either at foot or above, should first be drawn = 10 inches, or 150°. Then at each end raise or let fall perpendiculars of Latitude, equal in length to 88 thirtieths, or 146½ fiftieths of an inch; according to the Plotting scale used.* The value of each degree may then be plotted off from the Table annexed.

Column II. shows the "Meridional Parts," in ′, to every degree or Latitude. III. The "differences" to each degree; and IV. their value on thirtieths of an inch. Col. V. shows the progressive sums of Col. IV., so that with a Plotting-scale of 30 to an inch, each degree, from 30° to 60°, may be marked, without moving the Scale from the paper; for example, Lat. 40° will be 24·5 thirtieths from the upper horizontal line of Longitude. Columns VII. and VIII. are for a Plotting-scale of 50 to 1 inch. As to the Longitudes, those on the upper line may be marked from 0° to 150° E., which will suit the tracks from 18° W. of the Cape of Good Hope, to Australia; and the lower line may be marked from 145° E., to 65° W., which will suit the tracks from Australia and N. Zealand, to the west coast of S. America, or Cape Horn.

---

* $\frac{88}{30} = \frac{146\frac{1}{2}}{50}$ = 2·939 inches, for the *depth* of the Chart.

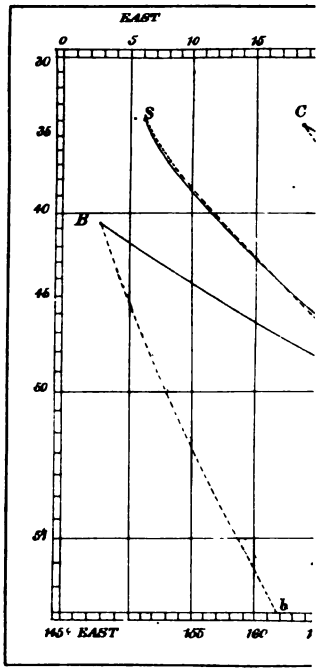

EAST
0
5
10
15
30
35
40
45
50
S
C
B
b
EAST
155
160

TABLE FOR MERCATOR'S CHART.

Scale 15° Long. to 1 inch.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Lats.	Mer.Prts.	Diff	Thirtieths.		Lats.	Fiftieths.		Lats.
30°	1888·4							
31°	1958·0	69·6	2·3	2·3	31°	3·9	3·9	31°
32°	2028·4	70·4	2·4	4·7	32°	3·9	7·8	32°
33°	2099·5	71·1	2·4	7·1	33°	3·9	11·7	33°
34°	2171·5	72·0	2·4	9·5	34°	4·0	15·7	34°
35°	2244·3	72·8	2·4	11·9	35°	4·0	19·7	35°
36°	2318·0	73·7	2·5	14·4	36°	4·1	23·8	36°
37°	2392·6	74·6	2·5	16·9	37°	4·1	27·9	37°
38°	2468·3	75·7	2·5	19·4	38°	4·2	32·1	38°
39°	2544·9	76·6	2·5	21·9	39°	4·3	35·4	39°
40°	2622·7	77·8	2·6	24·5	40°	4·3	40·7	40°
41°	2701·6	78·9	2·6	27·1	41°	4·4	45·1	41°
42°	2781·7	80·1	2·7	29·8	42°	4·5	49·6	42°
43°	2863·1	81·4	2·7	32·5	43°	4·5	54·1	43°
44°	2945·8	82·7	2·8	35·3	44°	4·6	58·7	44°
45°	3029·9	84·1	2·8	38·1	45°	4·7	63·4	45°
46°	3115·5	85·6	2·8	40·9	46°	4·8	68·2	46°
47°	3202·7	87·2	2·9	43·8	47°	4·8	73·0	47°
48°	3291·5	88·8	3·0	46·8	48°	4·9	77·9	48°
49°	3382·1	90·6	3·0	49·8	49°	5·0	82·9	49°
50°	3474·5	92·4	3·1	52·9	50°	5·1	88·0	50°
51°	3568·8	94·3	3·2	56·1	51°	5·2	93·2	51°
52°	3665·2	96·4	3·2	59·3	52°	5·4	98·6	52°
53°	3763·8	98·6	3·3	62·6	53°	5·5	104·1	53°
54°	3864·6	100·8	3·4	66·0	54°	5·6	109·7	54°
55°	3968·0	103·4	3·5	69·5	55°	5·7	115·4	55°
56°	4073·9	105·9	3·5	73·0	56°	5·9	121·3	56°
57°	4182·6	108·7	3·6	76·6	57°	6·0	127·3	57°
58°	4294·3	111·7	3·7	80·3	58°	6·2	133·5	58°
59°	4409·1	114·8	3·8	84·1	59°	6·4	139·9	59°
60°	4527·4	118·3	3·9	88·0	60°	6·6	146·5	60°

Explanation of Chart.

This Chart is constructed on a scale of 15° of Longitude to 1 inch, according to the Table in page 109; and when once the degree distances of Latitude are laid down on a strip of paper, from that Table, any number of similar charts (blank) may be quickly and correctly constructed. (See footnote, page 99.)

The black line from C to T, is the Composite route, by *Mr. Fisher's method*, from the Cape of Good Hope to Hobart Town, with a maximum latitude of 50° South, (p. 100). The dotted line shews the true Great Circle track as far as 60° S. By the *usual* Composite route, with a maximum latitude of 50° S. this would be followed as far as 36° 28′ E.; the vessel would now run down the parallel of 50° to 137° 42′ E., (footnote, page 100,) and then take up the Great Circle route again.

The black line from B to H, is the Composite route by *Mr. Fisher's method*, from Bass's Straits to Cape Horn, with a maximum latitude of 60° S. (p. 101). The dotted line shews the true Great Circle track as far as 60° S. By the *usual* Composite route, with a maximum latitude of 60° S. this would be followed as far as 161° 46′ E. and the parallel of 60° run down as far as 71° 10′ W. (*i.e.* from *b* to *d*), and then the remainder by Great Circle.

The black line from P to H is the Composite route by *Mr. Fisher's method*, from the outside of Cook's Straits to Cape Horn, with a maximum latitude of 57° S. (p. 102). The dotted line shows the Great Circle track; and where it crosses the parallel of 57° S. (166° 15′ W.) would be the place where, by the *usual* Composite route, a vessel would run down the parallel of 57° S. as far as 68° 49′ W. or from *p* to *h*.

The black line from S to V, is the Composite route by *Mr. Fisher's method*, from Port Jackson to Valparaiso, with a maximum latitude of 58¼° S. (p. 103 and p. 97). The dotted line shews the Great Circle track; and where it crosses the parallel of 58¼° S. (114¾° W.) would be the place where, by the *usual* Composite route, a vessel would run down the parallel of 58¼° S. as far as 166° 25′ W. or from *s* to *v*.

APPENDIX E.

Variation of the Compass.

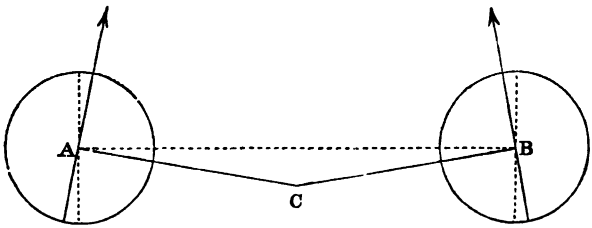
In obtaining the error of the Compass from an observation of the Sun's Amplitude or Azimuth (pages 42 and 50), it is to be remembered that this error includes not only the *variation*, properly so called, due to the Earth's magnetism,—but the *deviation* due to the iron in the ship.

This *deviation* varies according to the direction of the ship's head; so that if, after finding the whole error by Amplitude or Azimuth, the *same course* is kept, it does not matter to know how much of this error is due to the Earth's, and how much to the ship's magnetism. But if the course *be altered* before another observation can be taken, the application of the whole error (as if it were all due to *variation*) to the ship's new course, would give rise to considerable error in a vessel of war, or one built of iron.

The general effect of the iron in the ship is, in North magnetic latitude,* to draw the N. point of the needle to the East, when the ship's head is towards the East; and to the West, when the ship's head is towards the West. When the ship's head is N. or S. (or nearly so—for it differs in different ships (and even in the same ship, at different times), there is no *deviation*.

Let A and B represent two places due East and West of each other. A ship at A, with her head towards B, will, in N. magnetic latitude, have the N. point of her compass drawn Eastward, say 1 Point. In this case, supposing terrestrial variation not to exist, or else to be eliminated, the "correct magnetic" bearing of B, will be E. by N. Again at B, with her head towards the West, the N. end of the needle will be drawn towards the West, by 1 Point, and the

* The magnetic Equator, or line of no "dip," does not quite coincide with the terrestrial Equator.



bearing of A will be W. by N. If, not knowing the effect of this local deviation, the vessel were to steer East from A (or West from B), she would be in danger of running on the reef C.

Deviation is allowed for in the same way as *variation; i.e.* the observer is supposed to stand in the centre of the Compass, and to allow to the left if the variation or deviation is Westerly, and to the right if Easterly.

Example. Let the Compass bearing be N. 88° W. The *variation* 24° W.; and *deviation* 8° W. Required the true bearing.

by Compass,	N. 88° W.	
Variation 24° W.	+ 24	
	N. 112° W.	= S. 68° W. or "correct magnetic."
Deviation 8° W.		— 8°
		S.60 W. "True" bearing.

The variation and deviation being, in this case, the same (both Westerly), the result is the same as if their sum were applied to the left of the Compass bearing, or N. 120° W.

Suppose a vessel steering by compass S. 85° E., finds by an Amplitude or Azimuth, that her compass is out 16° W., and that her *true* course is N. 79° E. As long as she keeps this course, there is no need to know how much is due to *deviation;* but should she alter her course, say by Compass to N. 41° W., the want of this knowledge might, if she had much iron about her, lead to grave consequences. Suppose, as is often the case, the error of 16° W. were considered to be all due to *variation*, it would now be supposed she was steering *true* N. 57° W.; but had the *deviation* been 6° E., when her head was S. 85° E., and 4° W. when her head was N. 41° W., her true present course would be N. 67° W. The *variation* would be the

same (22° W.) on both courses; but on the Easterly course the total error = 22° — 6°, and on the N. Westerly course the error = 22° + 4°.

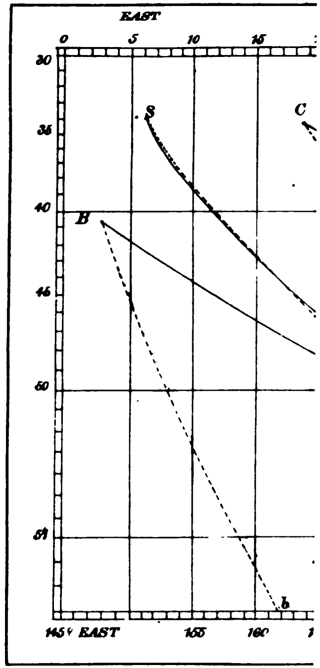
The *deviation* for every point of the Compass at which the ship's head may be pointed, should be entered in a Table. This Deviation is obtained when the vessel is near the shore, and the *Variation known*, by swinging the ship's head to every point of the Compass, and comparing the bearing of the ship's compass from a place on shore, with the bearing of the shore station from the ship, as read by the ship's compass. The error, after allowing for Variation in both compasses, is the Deviation.

Since the greatest Deviation is generally greatest when the ship's head is East or West,* it is usual when it is required at sea, to turn the vessels head to the East and West in quick succession, taking an observation of the sun for Amplitude or Azimuth at each instant. Both the Variation and *maximum* Deviation are then obtained; the former being half the *sum* of the errors of the Compass, and the latter, half the *difference*. Thus, if the whole error, when the ship's head is East, is 16° W., and when her head is West, 28° W.; the *Variation* $= \frac{28 + 16}{2} = 22°$ W. The maximum Deviation $= \frac{28° - 16}{2} = 6°$; which being found, the Deviation at intermediate Points is easily calculated, as it varies according to the sines of the Points, the maximum Deviation being considered the hypothenuse of the triangle. Thus, in the above Example, where the maximum Deviation or hypothenuse = 360′, and we require the Deviation at 2 Points (*i.e.* N.N.E.—N.N.W.—S.S.E.—S.S.W.), we have sin. 90° : 360′ :: sin. 22° 30′ : 138′ (or 2°18′).

Astronomical Memoranda.

In looking at a Celestial Globe, it will be observed that the Signs of the zodiac do not agree with the Constellations of the same name; for instance the *Sign* ♉ (Taurus) marked on the Ecliptic is

* It does not always follow that the maximum deviation is *exactly* at the E. and W. points, nor that if it is at a maximum at E, it is also at a maximum at W. In the above example, the two maxima may be 6½° and 5½°, the *sum* being 12° as before.



EAST
0
5
10
15
30
35
40
45
50
S
C
B
b
145° EAST
155
160

TABLE FOR MERCATOR'S CHART.

Scale 15° Long. to 1 inch.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Lats.	Mer.Prts.	Diff.	Thirtieths.		Lats.	Fiftieths.		Lats.
30°	1888·4							
31°	1958·0	69·6	2·3	2·3	31°	3·9	3·9	31°
32°	2028·4	70·4	2·4	4·7	32°	3·9	7·8	32°
33°	2099·5	71·1	2·4	7·1	33°	3·9	11·7	33°
34°	2171·5	72·0	2·4	9·5	34°	4·0	15·7	34°
35°	2244·3	72·8	2·4	11·9	35°	4·0	19·7	35°
36°	2318·0	73·7	2·5	14·4	36°	4·1	23·8	36°
37°	2392·6	74·6	2·5	16·9	37°	4·1	27·9	37°
38°	2468·3	75·7	2·5	19·4	38°	4·2	32·1	38°
39°	2544·9	76·6	2·5	21·9	39°	4·3	35·4	39°
40°	2622·7	77·8	2·6	24·5	40°	4·3	40·7	40°
41°	2701·6	78·9	2·6	27·1	41°	4·4	45·1	41°
42°	2781·7	80·1	2·7	29·8	42°	4·5	49·6	42°
43°	2863·1	81·4	2·7	32·5	43°	4·5	54·1	43°
44°	2945·8	82·7	2·8	35·3	44°	4·6	58·7	44°
45°	3029·9	84·1	2·8	38·1	45°	4·7	63·4	45°
46°	3115·5	85·6	2·8	40·9	46°	4·8	68·2	46°
47°	3202·7	87·2	2·9	43·8	47°	4·8	73·0	47°
48°	3291·5	88·8	3·0	46·8	48°	4·9	77·9	48°
49°	3382·1	90·6	3·0	49·8	49°	5·0	82·9	49°
50°	3474·5	92·4	3·1	52·9	50°	5·1	88·0	50°
51°	3568·8	94·3	3·2	56·1	51°	5·2	93·2	51°
52°	3665·2	96·4	3·2	59·3	52°	5·4	98·6	52°
53°	3763·8	98·6	3·3	62·6	53°	5·5	104·1	53°
54°	3864·6	100·8	3·4	66·0	54°	5·6	109·7	54°
55°	3968·0	103·4	3·5	69·5	55°	5·7	115·4	55°
56°	4073·9	105·9	3·5	73·0	56°	5·9	121·3	56°
57°	4182·6	108·7	3·6	76·6	57°	6·0	127·3	57°
58°	4294·3	111·7	3·7	80·3	58°	6·2	133·5	58°
59°	4409·1	114·8	3·8	84·1	59°	6·4	139·9	59°
60°	4527·4	118·3	3·9	88·0	60°	6·6	146·5	60°

9·8565 s. in 1 Mean Solar hour. This is called the "ACCELERATION" of Sidereal on Mean Solar time, and is added to Mean Solar, to obtain Sidereal time.

TABLE II.—"*Acceleration.*"

H	M	S	M	S	M	S	S	Dec.	S	Dec.
1	0	9·86	1	0·16	31	5·09	1	·00	31	·08
2	0	19·71	2	0·33	32	5·26	2	·00	32	·09
3	0	29·57	3	0·49	33	5·42	3	·01	33	·09
4	0	39·43	4	0·66	34	5·58	4	·01	34	·09
5	0	49·28	5	0·82	35	5·75	5	·01	35	.10
6	0	59·14	6	0·99	36	5·91	6	·02	36	·10
7	1	9·00	7	1·15	37	6·08	7	·02	37	·10
8	1	18·85	8	1·31	38	6·24	8	·02	38	·10
9	1	28·71	9	1·48	39	6·41	9	·02	39	·11
10	1	38·56	10	1·64	40	6·57	10	·03	40	·11
11	1	48·42	11	1·81	41	6·73	11	·03	41	·11
12	1	58·28	12	1·97	42	6·90	12	·03	42	·12
13	2	8·13	13	2·13	43	7·06	13	·04	43	·12
14		17·99	14	2·30	44	7·23	14	·04	44	·12
15	2	27·85	15	2·46	45	7·39	15	·04	45	·12
16	2	37·70	16	2·63	46	7·56	16	·04	46	·13
17	2	47·56	17	2·79	47	7.72	17	·05	47	·13
18	2	57·41	18	2·96	48	7·89	18	·05	48	·13
19	3	7·27	19	3·12	49	8·05	19	·05	49	·13
20	3	17·13	20	3·29	50	8·21	20	·05	50	·14
21	3	26·99	21	3·45	51	8·38	21	·06	51	·14
22	3	36·84	22	3·61	52	8·54	22	·06	52	·14
23	3	46·70	23	3·78	53	8·71	23	·06	53	·15
24	3	56·56	24	3·94	54	8·87	24	·07	54	·15
			25	4·11	55	9·04	25	·07	55	·15
			26	4·27	56	9·20	26	·07	56	·15
			27	4·43	57	9·36	27	·07	57	·16
			28	4·60	58	9·53	28	·08	58	·16
			29	4·76	59	9·69	29	·08	59	·16
			30	4·93	60	9·86	30	·08	60	·16

Thus xiv.h. 12 m. 16 s. Mean Solar Time = xiv.h. 12 m. 16 s. *plus* 2 m. 20·0, = xiv.h. 14 m. 36 s. Sidereal Time.

Equation of Time, and "Mean" and "Apparent" Time.

Since the Sun *varies its speed* in different parts of its Orbit, and also *moves on the Ecliptic at an angle* to the Equinoctial (27° 23½′), the length of an "Apparent" Solar day, (or the interval between two successive transits of the Sun,) fluctuates slightly. As no watch could be made to keep this irregularity, a *Mean* Solar day is adopted as a *constant* interval of time, and is the mean or average of all the Apparent Solar days in the year. An imaginary Sun called the "Mean Sun" is conceived to move uniformly and in the Equator, with the real Sun's *mean* motion in Right Ascension; and the interval between the departure of any meridian from the *Mean* Sun, and its succeeding return, is the Mean Solar day, divided into 24 Mean Solar hours, and to which time clocks and watches are adjusted. The time deduced from observations of the *real* Sun, is called "Apparent" time, and is that shown by a Sun-dial. The "Mean" time is found from this, by applying a fluctuating difference called the "Equation of Time," given in Table III. The true Sun is only on the meridian four times in the year when the Mean time watch is at XII., namely, about the 15th April, 15th June, 1st September, and 24th December.

TABLE III.—"*Equation of Time.*"

Day.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Add.	*Add.*	*Add.*	*Add.*	*Sub.*	*Sub.*	*Add.*	*Add.*	*Sub.*	*Sub.*	*Sub.*	*Sub.*
	m.	m.	m.	m.	m.	m.	m.	m.		m.	m.	m.
1	3¾	13¾	12¾	4	3	2½	3½	6	0	10¼	16¼	10¾
2	4¼	14	12½	3¾	3¼	2½	3½	6	0¼	10½	16¼	10½
3	4¾	14	12¼	3½	3¼	2¼	3¾	6	0½	10¾	16¼	10
4	5¼	14¼	12	3¼	3¼	2	4	5¾	0¾	11¼	16¼	9½
5	5½	14¼	11¾	2¾	3½	2	4¼	5¾	1¼	11½	16¼	9¼
6	6	14½	11½	2½	3½	1¾	4¼	5¾	1½	11¾	16¼	9
7	6½	14½	11¼	2¼	3½	1½	4½	5½	2	12	16¼	8½
8	6¾	14½	11	2	3¾	1¼	4¾	5½	2¼	12¼	16	8
9	7¼	14½	10¾	1¾	3¾	1	4¾	5¼	2¾	12½	16	7½
10	7¾	14½	10½	1½	3¾	0¾	5	5¼	3	13	16	7
11	8¼	14½	10¼	1¼	3¾	0½	5	5	3¼	13¼	16	6½
12	8½	14½	10	0¾	4	0½	5	4¾	3¾	13½	15¾	6¼
13	8¾	14½	9¾	0½	4	0¼	5¼	4¾	4	13¾	15½	5½
14	9¼	14½	9½	0¼	4	0¼	5½	4½	4½	14	15½	5¼
				Sub.		*Add.*						
15	9½	14½	9¼	0	4	0¼	5½	4¼	4¾	14¼	15¼	4¾
16	10	14¼	9	0¼	4	0¼	5¾	4	5¼	14½	15	4¼
17	10¼	14¼	8½	0½	4	0½	5¾	3¾	5½	14¾	14¾	3¾
18	10½	14¼	8¼	0¾	4	0½	6	3¾	6	14¾	14¾	3¼
19	11	14¼	8	1	3¾	0¾	6	3½	6¼	15	14½	2¾
20	11¼	14	7¾	1¼	3¾	1	6	3¼	6½	15¼	14¼	2¼
21	11½	14	7½	1¼	3¾	1¼	6	3	7	15¼	14	1¾
22	11¾	13¾	7¼	1½	3¾	1½	6	2¾	7¼	15½	13¾	1¼
23	12	13¾	6¾	1¾	3½	1¾	6	2½	7¾	15½	13½	0¾
												Add.
24	12¼	13½	6½	2	3½	2	6	2¼	8	15¾	13¼	0¼
25	12½	13½	6¼	2	3½	2¼	6¼	2	8¼	15¾	13	0½
26	12¾	13¼	5¾	2¼	3¼	2¼	6¼	1¾	8¾	16	12½	1
27	13	13	5½	2½	3¼	2½	6¼	1½	9	16	12¼	1¼
28	13¼	13	5¼	2½	3	2½	6¼	1¼	9¼	16	12	1¾
29	13½	12¾	4	2¾	3	2¾	6¼	1	9¾	16¼	11½	2¼
30	13½		4¾	3	2¾	3	6	0¾	10	16¼	11¼	2¾
31	13¾		4½		2¾		6	0½		16¼		3¼

The word "*add*" denotes that the Equation of Time is to be added to Apparent (or Sun-dial) Time, in order to obtain Mean (or Clock) Time.

Conversion of Arc into Time.

(See page 41).

Conversion of Longitude into R.A.

(See page 48).

The Moon.

The *Mean* distance of the Moon from the centre of the Earth is 237630 miles, or nearly 60 radii of the Earth, so that it is sensibly nearer when *on the Zenith.* (In perigee its distance is 221290, and in apogee 251760). The diameter is 2153 miles. She comes to the Meridian, *on an average* 48 m. earlier every day, and her motion *Eastward* through the stars is on a mean, 13° 10½′ per diem, whilst the Sun in the same time progresses eastward through the stars 59′ 8″ per day; so that the Moon gains on the Sun on an average about 12·2 degrees a day. (Since the Moon's diameter averages 31¼′ and her actual motion 31⅜′ per hour, she progresses Easterly through the stars, nearly her own diameter per hour.)

The period of the Moon's revolution round the Earth, reckoning from her departure from, till her return to, a particular star, is her "Sidereal Revolution," or 27 d. 7 h. 44 m.; but in the meantime, the Earth has advanced in her orbit, in the same direction, about 27°; so that at the rate of 13·2° per diem, it takes the Moon 2 days and 5 hours to catch up the Sun, and complete her "Synodic Revolution" of 29 d. 12 h. 44 m. It is this that is generally spoken of as a *Lunation.*

A "Node" is the point of the Ecliptic where the Moon (or a Planet) in its orbit, cuts the Ecliptic. The *ascending* Node ☊ is the point of intersection as the Moon travels Northwards. The inclination of the Moon's orbit to the *Ecliptic*, is 5° 8′ 48″, and as the inclination of the Earth's orbit to the *Equator* is 23° 27½′, the Moon's declination can never be above 28° 37′. The Nodes of the Moon have a retrograde motion, of the same kind as the Sun in the "precession of the equinoxes;" but it is much greater, being about 1° 30′ every month; so that in 18·6 years (called the Moon's cycle) she will have made an entire circuit, westerly, of the Ecliptic.

The Moon rotates on its axis in exactly the same time that it makes its "Synodic Revolution," so that we on the Earth always see the same portion of the Moon towards us.

A visual angle of 1″ from the Earth subtends on the Moon's surface $\frac{237630}{206265} = 1{\cdot}15$ miles.

Motion of the Moon in "Lunars."

Since the *Mean* motion of the Moon on that of the Sun, is (as above shewn) about 13·2° in 24 hours, or 360° of Longitude, an error of 1° in the observed "Distance" would on an average cause an error of $\frac{360^\circ}{13{\cdot}2^\circ} = 27{\cdot}3^\circ$; and an error of 1′ in Distance an error of 27·3′ of Longitude, or 1 m. 49 s. of Time.

However, as the minutes of Longitude are only equal to Nautical miles, when on the Equator, and decrease towards the Poles as the cosine of the Latitude, the error in Nautical *miles* for 1′ of Distance, will in any Latitude, be 27·3 × cos. Lat. So in Lat. 50° 12′ (North or South) an error of 1′ in the observed Distance will, at the Moon's Mean rate of motion, cause an error of 27·3 × ·64 or 17½ Nautical miles.

The error is at a minimum when the Moon gains most rapidly on the Sun, or 14° in 24 h. The error is then $\frac{360}{14} = 25{\cdot}7'$ of *Longitude*, or 1 m. 43 s. of *Time*, for 1′ of Distance. When the Moon gains least rapidly, or 10·2° in 24 h., the error is $\frac{360}{10{\cdot}2} = 35{\cdot}3'$ of *Longitude*, or 2 m. 21 s. of *Time* for 1′ of Distance. These minutes of Longitude to be reduced to Nautical *miles*, must be multiplied by the cosine of the Latitude.

The "Proportional logarithms" attached to the "Lunar Distances" of the Sun in the Nautical Almanac, serve to point out the rate of the Moon's motion, and—when a Star is observed with the Moon,—which Star is most favourable; that Star being preferred which has the *least* proportional log. attached; for the greater the

velocity, the less the effect of an error in the observed Distance. For example, Aug. 11, 1863, the P. L. for the Sun's Distance is ·3539 ; this is 1° 19′ 41″ for III. hours, or 10·224° in XXIV. hours. So again on the 24th March, 1865, the P. L. = ·2333 = 1° 45′ 12″ for III. hours, or 14·024° for XXIV. N.B. The P. L. in these pages of the Nautical Almanac, refers to the change in III. hours between the Distance to which the P. L. is attached, and the *next* Distance following it.

Proportional Logarithms in Lunar Observations.

All the observations can be taken by one person, and the "Times" and "Altitudes" of the several observations can be reduced to the Time of the observation of the Lunar Distance, by using Proportional Logarithms, as follows:

Times by Watch.

h.	m.	s.			°	′	″	
21	38	24	Alt. Sun's l. l.	=	13	51	0	Required the Altitudes at the moment the "Distance" was observed, i.e. 21h. 49m. 33s.
21	42	8	Alt. Moon's u. l.	=	27	25	20	
21	49	33	DISTANCE	=	81	46	57	
21	55	57	Alt. Moon's u. l.	=	25	24	20	
22	0	27	Alt. Sun's l. l.	=	15	48	40	

SUN.

As Interval between alts. 22m. 3s. Arith. compl. Prop. log. 9·0881
Is to 1st alt. to Distance 11m. 9s. Prop. log. . . . . . 1·2080
So is Change of Altitude + 1° 57′ 40″ Prop. log. . . . . 0·1846

+ 0° 59′ 30″ = 0·4807
13° 51′ 0″

Sun's Alt. at 21h. 49m. 33s. 14° 50′ 30″

MOON.

As Interval between Alts.	13m. 49s.	Arith. compl. Prop. log.	8·8851
Is to 1st Alt. to Distance	7m. 25s.	Prop. log.	1·3851
So is change of Altitude	— 2° 1′	Prop. log.	0·1725
		— 1° 4′ 57″ =	0·4427
		27° 25′ 20″	
	Moon's Alt. at 21h. 49m. 33s.	26° 20′ 23″	

The usual method would be

I. 22·05m. : 11·15m. :: 1·96° : 0·99°
II. 13·82m. : 7·42m. :: 2·02° : 1·08°

N.B.—The heavenly body farthest from the Meridian should be observed first and last, as its *rate* of motion varies least, though its *actual* motion is quickest.

Eclipses.

Since in a course of a Lunation, the Moon is once between the Earth and the Sun, and once places the Earth between itself and the Sun, there would in every Lunar month be an Eclipse of the Sun, and also an Eclipse of the Moon, *if* the Moon's orbit were in the same plane as the Earth's orbit or Ecliptic, because on each of the two occasions all three luminaries would be in a direct line. Owing however to the Moon's orbit being somewhat inclined, (5° 8′ 48″) to the Earth's orbit or Ecliptic, it passes when at New and Full, generally above or below the line * that would join the three luminaries. But on those few occasions when the moon in her node (*i.e.* when her latitude = 0°) has a longitude the same as

* There *must* be an Eclipse, more or less, of the Moon, if when at Full, she is not more than 9° 24′ from her node; and *may* take place if within 11½°. If she is less than 3° 54′, it will be total.

the longitude of the Sun's longitude, there will be an Eclipse of the *Sun*, if it is conjunction or New Moon, and when the Sun's longitude is 180° from the Moon in her node, there will be an Eclipse of the *Moon*, if it is opposition or Full Moon.

Seven is the greatest number of Eclipses that can happen in a year; and *two* the least. If there are seven, five must be of the Sun, and two of the Moon. If there be only two, both must be of the Sun; for in every year there are *at least* two Solar Eclipses. There can never be more than three Lunar Eclipses in a year, and in some years none at all.

Though there are four Solar Eclipses to three Lunar, yet there are more Lunar Eclipses visible in any particular place; because while a Lunar Eclipse is visible to an entire hemisphere, a Solar Eclipse is only visible to a small part of the Earth. This arises from the relative magnitude of the Sun and Moon: the former throwing its shadow far beyond the orbit of the Moon.

An eclipse of the Sun is *total* when the Moon's real shadow or "umbra" extends beyond the Earth's surface. For some distance around this spot, that is to say, within the "penumbra" (or shadow of the *edge* of the sun), there will be a *partial* Eclipse.

When the shadow of the moon does not extend to the Earth, a spectator situated in the prolongation of the axis of the conical shadow will see an *annular* eclipse of the sun. A *total* eclipse cannot last above seven minutes, the belt of the Earth's surface covered by it seldom exceeding 2°. A total eclipse of the *Moon* may last 1¾ hours.

Nautical Almanac.

"Sidereal Time" is the same as "Right Ascension of the Mean Sun." The "Sidereal time at Mean Noon" is therefore the Right Ascension of the Mean Sun, at Mean Noon; *i.e.* the angular distance of the first point of Aries, or the true Vernal Equinox, from the Meridian, at Mean Noon; or the time which ought to be shown by a Sidereal Clock *at Greenwich*, when the Mean Time clock is at XII. The Sidereal clock shows 0h. 0m. 0s. every 24 (Sidereal) hours when the first point of Aries is on the Meridian at Greenwich.

If the place of observation be *not on the meridian of Greenwich*, the "Sidereal time," or "Right Ascension of the Mean Sun," must be corrected, by adding the "Acceleration" 9·86s. per hour of Longitude, if the place be to the *west* of Greenwich, and subtracting it if *east*. This is requisite on account of the Sun's R. A. varying 3m. 56·55s. every 24 hours. A star's R. A. does not vary at all.

The "Mean time of Transit of the first point of Aries" is the distance of the *mean sun* from the Meridian, when the first point of Aries (or true point of intersection of the Ecliptic and Equator) is on the Meridian of Greenwich, or the "Mean time at Sidereal Noon." It is the time which a Mean time clock should shew at Greenwich, when the Sidereal clock is at 0h. 0m. 0s.

To find the Time of Transit of a Star.

The rule in the footnote, p. 45, is near enough for all purposes at sea; but properly the Sun's A. R. is subject to a slight correction as just shewn, *if the place be not in the Meridian of Greenwich.*

Example. Required the Apparent, and the Mean Time of the transit of Aldebaran at a place in 45° (= 3h.) *East* Longitude, on the 16th Dec. (Astronomical time) 1864.

		h.	m.	s.
App. R. A. of Star, Dec. 16 (p. 354 Naut. Alm.)		4h.	28m.	12·58s.
Sun's R.A. at App. Noon Dec. 16 = 17h. 37m. 36·06s.				
Deduct "acceleration" at (9·86s. per hour) for 3h. *East* long. .	-- 29·57	— 17	37	6·49
		10	51	6·09
Diff. of Sun's App. R. A. at App. Noon, on the 16th and 17th Dec. . . . =	4m. 26·10s.			

Then 10h. 51m. 6·1s $\times \dfrac{4\quad 26{\cdot}10}{24h. + 4\quad 26{\cdot}10}$

$= \dfrac{39066{\cdot}1 \times 266{\cdot}1}{86666{\cdot}1} = 119{\cdot}95$ seconds — 1· 59·95

App. Time of transit . . . . = 10 49 6·14

App. R. A. of Star, Dec 16 (p. 345 Naut. Alm.)	4h.	28m.	12·58s.
Sidl. Time at Mn. Noon, Dec. 16 = 17h. 41m. 31·00s. . . . . *Deduct* "acceleration" as before — 29·57	—17	41	1·43
Sidl. interval from Mean Noon	10	47	11·15
Deduct "Retardation" at 9·83s. per h. . —		1	46·03
* MEAN TIME of transit . . . . =	10	45	25·12

Or App. R. A. of Star, Dec. 16 (p. 345 Naut. Alm.)	4h.	28m.	12·58s.
Deduct "Retardation" at 9·83s. per hour.			— 43·94
Interval in Solar Time	4	27	28·64
Mean time of Transit of 1st point of Aries, at Noon, Dec. 16 . . . . = 6h. 17m. 27·00s. *Plus* "Retardation" for 3h. E. Long. = 29·49	+ 6	17	56·49
* MEAN TIME of transit as before . . =	10	45	25·13

To find the Meridian Altitude.

The Meridian altitude of a celestial body = the *sum* of the Declination and Colatitude when they are of the same name, or their *difference* when of contrary names ; the altitude to be reckoned from the S. when the Latitude is N., and *vice versâ* ; but when the sum exceeds 90°, it is to be deducted from 180°, and the remaining altitude, reckoned from the S. in South Latitude and from the N. in North Latitude. Thus if the Latitude is 15° North, and the Star's Declination 20° North, the Meridian altitude will be 85° above the North point of the horizon.

To know what stars are visible in a given Latitude.

When the Polar Distance of a star (reckoning from the N. if the Latitude is N) exceeds 90° plus the Colatitude, the star is not visible at that place. Hence, in Lat. 51° N. no star whose S. Declination is greater than 39° is visible. When the Polar Distance is less than the latitude of the place, and of the same name, the star culminates both above and below the Pole.

* *The App. T.* of transit may also be found by applying the Eq. Time (from the monthly page ii. of Naut. Alm.) for the Mean Time interval of 10h. 45m. 25·12s. In this Example, 3m. 41·02s. is to be added to "Mean Time of Transit."

Stars.

There are supposed to be about 75 millions of Stars separately visible in a good telescope; but not more than 4000 visible to the naked eye, and only half of these *at a time*. These include 2500 stars of the 6th Magnitude, which many persons cannot see *as separate stars;* so that those who have not very good eyes, can only distinguish about 1500 *altogether*; namely:—I. Mag. = 20; II. Mag. = 50; III. Mag. = 250; IV. Mag. = 500; V. Mag. = 700. The following are the brightest stars, in order:—

α Canis Majoris (Sirius).	*α Crucis.
*α Argus (Canopus).	α Virginis (Spica).
*α^2 Centauri.	α Scorpii (Antares).
α Boötis (Arcturus).	α Piscis Australis (Fomelhaut).
β Orionis (Rigel).	α Leonis (Regulus).
α Aurigæ (Capella).	β Geminorum (Pollux).
α Canis Minoris (Procyon).	α^2 Geminorum (Castor).
α Lyræ (Vega).	α Aquilæ (Altair).
α Orionis (Betelguese).	*β Crucis.
*α Eridani (Achernar).	*γ Crucis.
α Tauri (Aldebaran).	*α Gruis.
*β Centauri.	α Cygni (Deneb).

(The first 20 are of the 1st Magnitude.) Then follow α, ϵ, and η, Ursa Majoris, ϵ Canis Majoris, ϵ Orionis, and α Hydræ (Alphard). The Polestar (α Ursa Minoris) is of the 2d Magnitude. η Argus in 1830 was a star of the 2d magnitude; in 1838 it became of the 1st, about equal to Arcturus; in 1843 it was equal to Canopus; since that time it has diminished to a star of the 2d magnitude. Its R. A. = 10h. 40m., and Decl. = 58° 51′ S. See also p. 131.

Venus.

Venus may often be observed in the day-time, especially in low latitudes, to the great advantage of the Navigator. The planet appears brightest when its elongation (or distance E. or W. of the

---

* The eight stars marked thus * are not visible in any North Lat. greater than 34°. The whole of the "Southern Cross" is visible as far North as Lat. 29° when the horizon is clear.

Sun) is about 40°, or about 5 weeks before and after inferior conjunction. At this time her diameter is about 40″, and her figure that of the crescent of the Moon 5 days old, the illuminated portion being about 13″. When Venus is at superior conjunction, her diameter is only about 10″, and hidden behind the Sun. When at inferior conjunction, the diameter is 62″, but then the dark side being towards the Earth she is nearly invisible. If at this time the planet is exactly in a line with the Sun, there is a "Transit of Venus" across the Sun. It often happens that when Venus in the day-time is very indistinct to the naked eye, she may be seen distinctly by reflection in the horizon glass of the Sextant, by setting the instrument to about the Altitude (either computed, or found on a Globe), and sweeping the horizon under the Planet.

Error of Altitude affecting the Hour Angle.

I. When the Latitude and the Azimuth are known, the formula in page 55 will suffice. *Example.* Lat. = 50° N. Azimuth = N. 36° E.

$$\frac{\text{Cos. lat. and Sin. azim.}}{\cdot 0667} = \frac{\cdot 643 \times \cdot 588}{\cdot 0667} = 5{\cdot}67' \text{ error of Altitude,}$$

makes a difference of 1 minute of Time in the Hour angle. Or, when the error in *Alt.* is known in minutes of arc, the error in *Time* in minutes is $\left(\frac{1}{\text{Cos. Lat.} \times \text{Sin. Az.}} \times \text{Error in Alt. in }'\right) \div 15.$

Thus Lat. 50° 48′ N.; Star bearing S. b. E.; and error of Alt. = 4′. The error in Time is 2·16 m.

II. When the Latitude, Polar Distance, and Hour angle observed, are given, $\frac{\text{Sin. P. D.} \times \text{Cos. lat.} \times \text{Sin. H. A.} \times 15}{\text{Cosine Alt.}}$ = the error of Altitude due to an error of 1 minute of Time in the Hour angle.

Example. Alt. = 49° 10′ P. D. = 67° 31′ Lat. = 32° 40′ H. A. = 45° 3′ then $\frac{\cdot 923 \times \cdot 842 \times \cdot 708 \times 15}{\cdot 654} = \frac{\cdot 550 \times 15}{\cdot 654} = 12{\cdot}61'$ error of Altitude to 1 minute of Time in the Hour angle.

APPENDIX F.

USEFUL TABLES AND NOTES.

The angles made by every Point and Quarter of a Point of the compass with the meridian.

		Points.	Angles.	Points.		
360° North.	360° North.		° ′ ″		180° South.	180° South.
		0¼	2 48 45	0¼		
		0½	5 37 30	0½		
11° 15′	348° 15′	0¾	8 26 15	0¾	168° 45′	191° 15′
N. b. E.	N. b. W.	I.	11 15 0	I.	S. b. E.	S. b. W.
		1¼	14 3 45	1¼		
		1½	16 52 30	1½		
22° 30′	337° 30′	1¾	19 41 15	1¾	157° 30′	202° 30′
N.N.E.	N.N.W.	II.	22 30 0	II.	S.S.E.	S.S.W.
		2¼	25 18 45	2¼		
		2½	28 7 30	2½		
33° 45′	326° 15′	2¾	30 56 15	2¾	146° 15′	213° 45′
N.E. b. N.	N.W. b. N.	III.	33 45 0	III.	S.E. b. S.	S.W. b. S.
		3¼	36 33 45	3¼		
		3½	39 22 30	3½		
45°	315°	3¾	42 11 15	3¾	135°	225°
N.E.	N.W.	IV.	45 0 0	IV.	S.E.	S.W.
		4¼	47 48 45	4¼		
		4½	50 37 30	4½		
56° 15′	303° 45′	4¾	53 26 15	4¾	123° 45′	236° 15′
N.E. b. E.	N.W. b. W.	V.	56 15 0	V.	S.E. b. E.	S.W. b. W.
		5¼	59 3 45	5¼		
		5½	61 52 30	5½		
67° 30′	292° 30′	5¾	64 41 15	5¾	112° 30′	247° 30′
E.N.E.	W.N.W.	VI.	67 30 0	VI.	E.S.E.	W.S.W.
		6¼	70 18 45	6¼		
		6½	73 7 30	6½		
78° 45′	281° 15′	6¾	75 56 15	6¾	101° 15′	258° 45′
E. b. N.	W. b. N.	VII.	78 45 0	VII.	E. b. S.	W. b. S.
		7¼	81 33 45	7¼		
		7½	84 22 30	7½		
90°	270°	7¾	87 11 15	7¾	90°	270°
East.	West.	VIII.	90 0 0	VIII.	East.	West.

Column 1 is just 180° difference, (or reverse) of Column 7. So Column 2 is the reverse of Column 6. (*E.g.* 146° 15′ is the reverse of 326° 15′.)

Nat. Sines, Tangents, &c. to every Quarter Point.

POINTS.	Sine.	Cosine.	Tan.	Co-tan.	POINTS.	Chord.
0	·0000	1·000	·0000	infinite.	VIII.	
0¼	·0491	·9988	·0491	20·35	7¾	·049
0½	·0980	·9952	·0985	10·15	7½	·098
0¾	·1467	·9892	·1483	6·741	7¼	·147
I.	·1951	·9808	·1989	5·027	VII.	·196
1¼	·2430	·9700	·2505	3·992	6¾	·245
1½	·2903	·9579	·3033	3·297	6½	·293
1¾	3369	·9415	·3578	2·795	6¼	·345
II.	·3827	·9239	·4142	2·414	VI.	·390
2¼	·4276	·9040	·4730	2·114	5¾	·438
2½	·4714	.8828	·5345	1·871	5½	·486
2¾	·5141	·8577	·5994	1·668	5¼	·533
III.	·5556	·8315	·6682	1·497	V.	·581
3¼	·5957	·8032	·7416	1·348	4¾	·627
3½	·6344	·7730	·8207	1·218	4½	·674
3¾	·6716	·7410	·9063	1·103	4¼	·720
IV.	·7071	·7071	1·000	1·000	IV.	·765
	Cosine.	Sine.	Co-tan.	Tan.		

VERNIER.

To estimate how near it will read to.

Reduce the value of each division of the Degree, on the limb, to seconds; and divide it by the total number of divisions on the Vernier.

Example.

A Sextant has each Degree on the limb divided into 4 parts. The Vernier has altogether 60 divisions. Here each of the 4 parts on the limb = 15′, or 900″. Then $\frac{900}{60} = 15''$; to which the Vernier will read.

OR

The parts on the limb being 4, and the divisions on the Vernier being 60, we have $\frac{3600''}{4 \times 60} = 15''$ as before (3600″ being constant).

VIBRATIONS OF THE COMPASS CARD.

Let a = extreme vibration one way.
b = extreme the other way.
c = extreme vibration 3d in direction of a.

Then $\frac{a + 2b + c}{4}$ = Mean point of Vibration.

DECIMALS OF AN HOUR.

MIN.	Dec.	MIN.	Dec.	SEC.	Dec.	SEC.	Dec.
1	·01667	31	·51667	1	·00028	31	·00861
2	·03333	32	·53333	2	·00056	32	·00889
3	·05000	33	·55000	3	·00083	33	·00917
4	·06667	34	·56667	4	·00111	34	·00944
5	·08333	35	·58333	5	·00138	35	·00972
6	·10000	36	·60000	6	·00167	36	·01000
7	·11667	37	·61667	7	·00194	37	·01028
8	·13333	38	·63333	8	·00222	38	·01056
9	·15000	39	·65000	9	·00250	39	·01033
10	·16667	40	·66667	10	·00278	40	·01111
11	·18333	41	·68333	11	·00306	41	·01139
12	·20000	42	·70000	12	·00333	42	·01167
13	·21667	43	·71667	13	·00361	43	·01194
14	·23333	44	·73333	14	·00389	44	·01222
15	·25000	45	·75000	15	·00417	45	·01250
16	·26667	46	·76667	16	·00444	46	·01278
17	·28333	47	·78333	17	·00472	47	·01306
18	·30000	48	·80000	18	·00500	48	·01333
19	·31667	49	·81667	19	·00528	49	·01361
20	·33333	50	·83333	20	·00556	50	·01389
21	·35000	51	·85000	21	·00583	51	·01417
22	·36667	52	·86667	22	·00511	52	·01444
23	·38333	53	·88333	23	·00639	53	·01472
24	·40000	54	·90000	24	·00667	54	·01500
25	·41667	55	·91667	25	·00694	55	·01528
26	·43333	56	·93333	26	·00722	56	·01556
27	·35000	57	·95000	27	·00750	57	·01583
28	·46667	58	·96667	28	·00778	58	·01611
29	·48333	59	·98333	29	·00806	59	·01639
30	·50000	60	1·000	30	·00833	60	·01667

86400 seconds, or 1440 minutes in 24 h. 1296000″ or 21600′ in 360°

CHRONOMETER.

	Sailing E.	Sailing W.
	The Chronometer has	
The land made unexpectedly.	*gained* more or lost less.	gained less or *lost* more.
The land not made so soon as expected.	gained less or *lost* more.	*gained* more or lost less.

Thus, a vessel in the Bay of Bengal, running in for the land of the Coromandel Coast, when it is 8 h. 45 m. A.M. Mean Time at Ship, finds her chronometer 3 h. 21 m.; or a difference of 5 h. 24 m. or 81° 00′ E. Longitude. She immediately after, *makes the land unexpectedly*, and finds an error of half a degree in the Longitude; *i.e.* that at 8 h. 45 m. Ship Time, the Chronometer *should have shown* 3 h. 23 m.; or a difference of 5 h. 22 m. = 80° 30′ the true Longitude.

PERIODIC STARS.

The star *o* Ceti, (Mira), in the neck of the "whale" is of a high 2d magnitude for about 14 days; it then decreases, till in 3 months it is invisible. It reappears after 5 months, and, in 3 months more, gradually increases to its maximum splendour.

Algol in the head of Medusa (β Persei) generally appears as of the 2d magnitude; but an interval of 7 hours occurs at the expiration of every 62 hours, during the first 3½ of which it gradually diminishes to the 4th magnitude, and, during the next 3½ hours, it increases to its maximum brightness.

The star δ Cephei passes from $3\frac{1}{2}$ magnitude to the 5th, in 91 hours; and back again in 38 hours.

The star β Lyræ has a period of 12 days, 22 hours; and in that time it first increases, then decreases, then increases again, and then decreases; so that it has 2 maxima and 2 minima. At the 2 maxima its lustre is $3\frac{1}{2}$, and at the minima $4\frac{1}{4}$ and $4\frac{1}{2}$.

The star α Orionis is sometimes nearly equal to β Orionis in lustre, and sometimes below it. The stars α ϵ η in Ursæ Majoris are slightly variable. The first is sometimes of first magnitude, and ϵ of the 3d; but in this constellation of 7 bright stars, (4 in the body, and 3 in the tail,) six are generally of the same magnitude, and δ (at the junction of tail and body,) less. A line from ϵ Urs. Maj. to the Polestar passes through the *north pole* (distant 1° 26′ from the Polestar;) so that when these 2 stars are at the same altitude, the Polestar is at its greatest eastern or western elongation, and its altitude is then the latitude of the observer. From α to η = $25\frac{1}{2}°$. The "Pointers" $5\frac{1}{2}°$ apart.

A star is said to *rise* "heliacally," when after being in conjunction with the sun, and consequently invisible, it rises so soon before the sun (say about $\frac{3}{4}$ an hour) as to be visible when just risen, in the morning twilight. (In a day or two more it rises so long before the sun, that it is no longer visible).

A star is said to *set* "heliacally," when just as it is setting, (and not before), it becomes visible in the evening twilight. It is then about $\frac{3}{4}$ hour after the sun. In a day or two more, it has gained on the sun, is immersed in its rays, and is no longer visible.

A star is said to rise or set "acronically," when it rises at sunset, or sets at sunrise.

A star is said to rise or set "cosmically," when it rises and sets exactly with the sun, and is therefore not visible at the time.

FORCE OF THE WIND.

The force is usually estimated from 1 a light air, to 12 a severe tempest. The observations in the 5th column refer to a large sailing vessel on a wind.

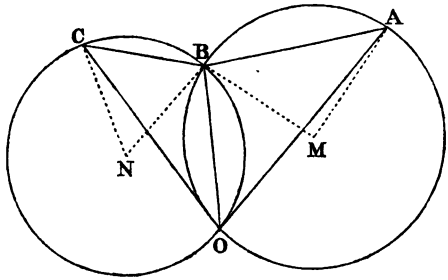
No.	Pressure in lbs. per square foot.	Velocity in miles per hour.		
I.	$\frac{1}{10}$ to $\frac{1}{3}$ lb.	4 to 7	Light airs.........	
II.	$\frac{1}{3}$ to $\frac{3}{4}$ lb.	7 to 12	Light breeze	Just fill the royals.
III.	$\frac{3}{4}$ to 1 lb.	12 to 15	Moderate breeze.	Just carry royals.
IV.	1 to $1\frac{1}{4}$ lbs.	15 to 17	Fine breeze........	Just carry top-gallt. sails.
V.	$1\frac{1}{4}$ to $1\frac{1}{2}$ lbs.	17 to 18	Fresh breeze	Top-gallt. sails and 1 reef.
VI.	$1\frac{1}{2}$ to 2 lbs.	18 to 20	Strong breeze	In top-gallant sails.
VII.	2 to $2\frac{1}{2}$ lbs.	20 to 24	Hard breeze.......	Double reefed topsails.
VIII.	$2\frac{1}{2}$ to $3\frac{1}{2}$ lbs.	24 to 30	Half a gale........	One reef in courses.
IX.	$3\frac{1}{2}$ to 7 lbs.	30 to 40	Whole gale........	Treble reefed topsails.
X.	7 to 10 lbs.	40 to 50	Hard gale..........	Close reefed topsails.
XI.	10 to 20 lbs.	50 to 60	Heavy gale........	Lying to.
XII.	20 to 30 lbs.	60 to 80	Tempest............	

To find the position of a ship or boat, from 2 angles to objects laid down on the Chart.

Ex. 1.—Let ABC in the figure, be three objects laid down on the Chart. The observer at O takes the angle $BOA = 46°$, and $BOC = 30°$. Join AB, BC; lay off the angles BAM, ABM, each equal to the complement of 46°, which is 44°; then the intersection of the lines AM, BM, is the centre of the circle ABO.

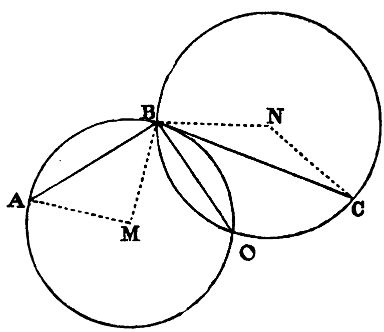
In like manner lay off BCN, CBN, each equal to the complement

of 30, which is 60°; then N is the centre of the circle CBO, and where the two circles cut, at O, is the place of the observer.



Ex. 2.—The angle between A and B is 47°; that between B and C is 107°.

Lay off ABM, BAM, each equal 43°; M is the centre of ABO.



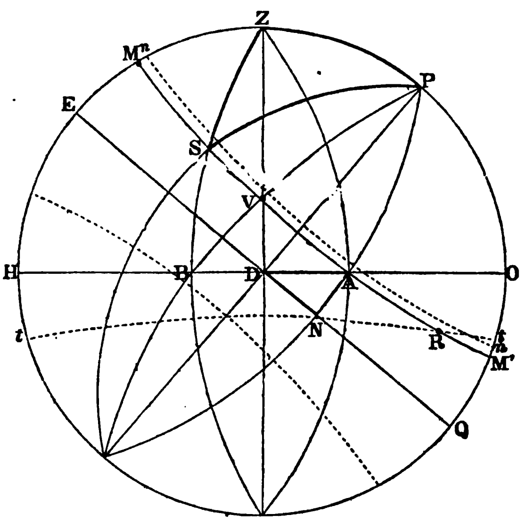
Lay off CBN, BCN, each equal to the complement of 107°, or 17°; then N is the centre of CBO; and where the two circles cut at O, is the place of the observer.

APPENDIX G.

(Pages 42 and 50.)

Projection of the Sphere, on the plane of the Meridian.

Let P be the elevated Pole,—EQ the Equinoctial,—HO the Horizon,—*nn* the sun's greatest declination, 23° 28′,—*tt* the line of twilight 18° below the horizon.



Then

OP or ODP = the latitude of the place.

MM′ = the sun's daily path at the place, that day.
(See NA, page 136.)

R = the sun emerging from darkness to twilight.

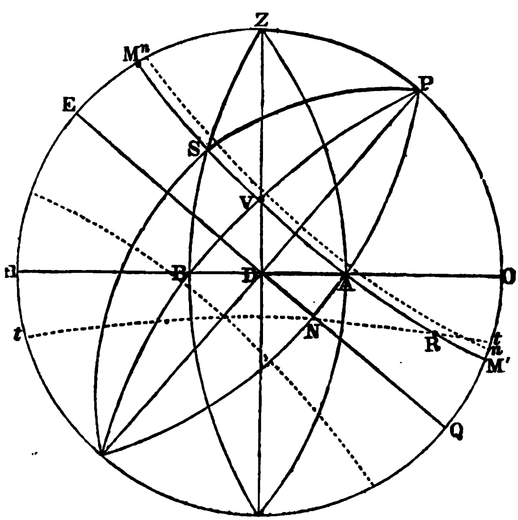
A = the sun rising on the horizon.

V = the sun when on the prime vertical.

S = the sun at an altitude of about 47°.
M = the sun when on the meridian.
DA, or DZA = the amplitude.
DN, or DPN = the ascensional difference.
NA = the sun's declination 20° North.
ADN, or QDO = the co-latitude.

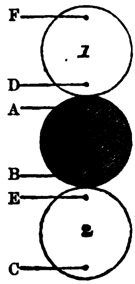
When the sun is at S.

ZS = zenith distance.
ZPS = hour angle from meridian, or about 3 h.
ZP = co-latitude.
PS = polar distance.
PZS = azimuth, or arc OB.



ARTIFICIAL HORIZON.

I. The *direct* telescope used.



When the sights are taken in the morning, A is the lower limb of the sun reflected direct on the mercury, and B the upper limb. C and D are the lower limbs reflected on the mercury through the sextant; the Sun in the morning appearing to rise from 2 to 1, and the angle increasing. The observation for contacts of the *lower* limb is read off when A and D are in contact; or for the *upper* limb when E and B are in contact.

II. The *inverting* telescope used.

The sun in the morning appears to fall from 1 to 2; and the observation for the *lower* limb is read off when E and B are in contact; or for the *upper* limb, when A and D are in contact.

N.B.—It is better not to use the turn-down coloured shades, but to screw on the red glass to the eye-piece.

In observing at *sea*, correct for Index Error, *Dip*, and Parallax; and for the remainder take out the Refraction. Then correct for Semi-diameter.

LONDON: R. CLAY, SON, AND TAYLOR, PRINTERS.

186, Fleet Street,
December, 1863.

Messrs. BELL and DALDY'S

NEW AND STANDARD PUBLICATIONS.

New Books.

JERUSALEM Explored; being a Description of the Ancient and Modern City, with upwards of One Hundred Illustrations, consisting of Views, Ground-plans, and Sections. By Dr. Ermete Pierotti, Doctor of Mathematics, Architect-Engineer to His Excellency Soorraya Pasha of Jerusalem, and Architect of the Holy Land. (Translated by the Rev. T. G. Bonney, M.A., Fellow of St. John's College, Cambridge.) 2 vols. impl. 4to. 5*l.* 5*s.* [*Immediately.*

The Customs and Traditions of Palestine compared with the Bible, from Observations made during a Residence of Eight Years. By Dr. Ermete Pierotti. 8vo. [*Preparing.*

British Seaweeds. Drawn from Professor Harvey's "Phycologia Britannica," with Descriptions in popular language by Mrs. Alfred Gatty. 4to. 3*l.* 3*s.* [*Ready.*

This volume contains drawings of the British Seaweeds in 803 figures, with descriptions of each, including all the newly discovered species; an Introduction, an Amateur's Synopsis, Rules for preserving and laying out Seaweeds, and the Order of their arranngement in the Herbarium.

Host and Guest: a Book about Dinners, Wines, and Desserts. By A. V. Kirwan, of the Inner Temple, Esq. Crown 8vo. [*Shortly.*

Alexander Hamilton and his Contemporaries; or, the Founders of the American Republic. By C. J. Riethmuller, Esq., Author of "Teuton, a Poem, " Frederick Lucas," a Biography. [*In the press.*

The Decline of the Roman Republic. By George Long, M.A. 8vo. Vol. I. [*In the press.*

Isaiah's Testimony for Jesus. With an Historical Appendix, and Copious Tabular View of the Chronology, from the Original Authorities. By William Brown Galloway, M.A., Incumbent of St. Mark's, Regent's Park, and Chaplain to the Right Hon. Viscount Hawarden. 8vo. 14*s*. [*Ready.*

The Book of Psalms; a New Translation, with Introductions and Notes, Critical and Explanatory. By the Rev. J. J. Stewart Perowne, B.D., Fellow of C. C. College, Cambridge, and Examining Chaplain to the Lord Bishop of Norwich. 8vo. Vol. I. [*Shortly.*

Life, Law, and Literature; Essays on Various Subjects. By William G. T. Barter, Esq., Barrister at Law. Fcap. 8vo. 5*s*. [*Ready.*

The Afternoon Lectures on English Literature. Delivered in the Theatre of the Museum of Industry, St. Stephen's Green, Dublin, in May and June, 1863. By the Rev. James Byrne, M.A., William Rushton, M.A., John K. Ingram, LL.D., Arthur Houston, M.A., the Rev. Edward Whately, M.A., Randal W. M'Donnell, Esq. Fcap. 8vo. 5*s*. [*Ready.*

The Divine Authority of the Pentateuch Vindicated. By Daniel Moore, M.A., Incumbent of Camden Church, Camberwell. Cr. 8vo. 6*s*. 6*d*. [*Ready.*

Bishop Colenso's Examination of the Pentateuch Examined. By the Rev. G. S. Drew, Author of "Scripture Lands," "Reasons of Faith." Crown 8vo. 3*s*. 6*d*. [*Ready.*

A Commentary on the Gospels for the Sundays and other Holy Days of the Christian Year. By the Rev. W. Denton, A.M., Worcester College, Oxford; and Incumbent of St. Bartholomew's, Cripplegate. 3 Vols. 8vo. 42*s*. [*Ready.*

Separately.

Vol. I. Advent to Easter. 15*s*.
Vol. II. Easter to the Sixteenth Sunday after Trinity. 14*s*.
Vol. III. Seventeenth Sunday after Trinity to Advent, and other Holy Days. 13*s*.

Daily Readings for a Year, on the Life of our Lord and Saviour Jesus Christ. By the Rev. Peter Young, M.A. *Third Edition, improved.* 2 vols. 8vo. 21*s*. Antique calf, 36*s*. Morocco, 40*s*. [*Ready.*

Notes and Dissertations, principally on Difficulties in the Scriptures of the New Covenant. By A. H. Wratislaw, M.A., Head Master of King Edward VI. Grammar School, Bury St. Edmunds, formerly Fellow and Tutor of Christ's College, Cambridge. 8vo. 7*s*. 6*d*. [*Ready.*

School Sermons. By the Rev. A. Jessopp, M.A., Head Master of the Grammar School, Norwich. Fcap. 8vo. [*In the press.*

The Book of Common Prayer. Ornamented with Head-pieces and Initial Letters specially designed for this edition. Printed in red and black at the Cambridge University Press. 24mo. Best morocco. 10*s*. 6*d*. Also in ornamental bindings, at various prices. [*Ready.*

Also a large paper Edition, crown 8vo. Best morocco, 18*s*. Also in ornamental bindings, at various prices. [*Ready.*

The Odes and Carmen Sæculare of Horace. Translated into English Verse by John Conington, M.A., Corpus Professor of Latin in the University of Oxford. *Second Edition.* Fcap. 8vo. Roxburgh binding, 5*s*. 6*d*.

On the Influence of Mechanical and Physiological Rest in the Treatment of Accidents and Surgical Diseases, and the Diagnostic Value of Pain. A course of Lectures, delivered at the Royal College of Surgeons of England in the years 1860, 1861, and 1862. By John Hilton, F.R.S., F.R.C.S., Member of the Council of the Royal College of Surgeons of England, late Professor of Anatomy and Surgery to the College, Surgeon and Lecturer on Surgery at the University of London, &c., &c. 8vo. 16*s*. [*Ready*.

A Fourth Series of Parables from Nature. By Mrs. Alfred Gatty. 16mo. 2*s*. [*Immediately*.

Baptista: A Quiet Story. With a Frontispiece. Crown 8vo. 6*s*. [*Ready*.

The Feasts of Camelot, with the Tales that were told there. By Mrs. T. K. Hervey. Fcap. 8vo. 4*s*. 6*d*. [*Ready*.

Arnold Delahaize; or, the Huguenot Pastor. With a Frontispiece. Fcap. 8vo. 5*s*. [*Ready*.

Denise. By the Author of "Mademoiselle Mori." 2 vols. Fcap. 8vo. 10*s*. [*Ready*.

The Adventures of a Little French Boy. With 50 Illustrations. Crown 8vo. Uniform with "Andersen's Tales," and "Robinson Crusoe." Cloth, gilt edges, 7*s*. 6*d*. [*Ready*.

Katie; or the Simple Heart. By D. Richmond, Author of "Annie Maitland." Illustrated by M. I. Booth. Crown 8vo. 6*s*. [*Ready*.

Glimpses into Petland. By the Rev. J. G. Wood, M.A., with Frontispiece by Crane. Fcap. 8vo. 3*s*. 6*d*. [*Ready*.

Mildred's Last Night; or, the Franklyns. By the Author of "Aggesden Vicarage." Fcap. 8vo. 4*s*. 6*d*. [*Ready*.

The Jew. A Poem. By Frederick Cerny. Fcap. 8vo. 2*s*. 6*d*. [*Ready*.

Poems and Songs, some of which are rendered from the Spanish. By Charles Welsh Mason. Fcap. 8vo. [*Ready*.

Original Acrostics. By a Circle of Friends. Fcap. 8vo. 2*s*. 6*d*. [*Ready*.

Dual Arithmetic. A New Art, by Oliver Byrne, formerly Professor of Mathematics at the late College of Civil Engineers, Putney. 8vo. 10*s*. 6*d*. [*Ready*.

Prosateurs Contemporains: or Selections in Prose, chiefly from contemporary French Literature. With English Notes. By F. E. A. Gasc. Fcap. 8vo. 5*s*. [*Ready*.

Chronological Maps. By D. Beale, author of "The Text-Book of English and General History."

No. I. England. 2*s*. 6*d*. [*Ready*.
No. II. Ancient History. 2*s*. [*Ready*.
Or bound together in One Vol., 3*s*. 6*d*.

BELL and DALDY'S POCKET VOLUMES. A Series of Select Works of Favourite Authors, adapted for general reading, moderate in price, compact and elegant in form, and executed in a style fitting them to be permanently preserved. Imperial 32mo.

Now Ready.

Burns's Poems. 2*s.* 6*d.*
Burns's Songs. 2*s.* 6*d.*
Walton's Complete Angler. Illustrated. 2*s.* 6*d.*
Sea Songs and Ballads. By Charles Dibdin and others. 2*s.* 6*d.*
White's Natural History of Selborne. 3*s.*
Coleridge's Poems. 2*s.* 6*d.*
The Robin Hood Ballads. 2*s.* 6*d.*
The Midshipman.—Autobiographical Sketches of his own early Career, by Capt. Basil Hall, R.N., F.R.S. From his "Fragments of Voyages and Travels." 3*s.*
The Lieutenant and Commander. By the same Author. 3*s.*
Southey's Life of Nelson. 2*s.* 6*d.*
Longfellow's Poems. 2*s.* 6*d.*
Lamb's Tales from Shakspeare. 2*s.* 6*d.*
George Herbert's Poems. 2*s.*
George Herbert's Works. 3*s.*
Milton's Paradise Lost. 2*s.* 6*d.*
Milton's Paradise Regained and other Poems. 2*s.* 6*d.*

Preparing.

Walton's Lives of Donne, Wotton, Hooker, &c.
The Conquest of India. By Capt. Basil Hall, R.N.
Gray's Poems.
Goldsmith's Poems.
Goldsmith's Vicar of Wakefield.
Henry Vaughan's Poems.
And others.

In cloth, top edge gilt, at 6*d.* per volume extra; in half morocco, Roxburgh style, at 1*s.* extra; in antique or best plain morocco (Hayday) at 4*s.* extra.

DR. RICHARDSON'S New Dictionary of the English Language. Combining Explanation with Etymology, and copiously illustrated by Quotations from the best authorities. *New Edition*, with a Supplement containing additional Words and further Illustrations. In Two Vols. 4to. 4*l.* 14*s.* 6*d.* Half bound in russia, 5*l.* 15*s.* 6*d.* Russia, 6*l.* 12*s.*

The WORDS—with those of the same Family—are traced to their Origin.

The EXPLANATIONS are deduced from the Primitive Meaning through the various Usages.

The QUOTATIONS are arranged Chronologically, from the Earliest Period to the Present Time.

*** The Supplement separately, 4to. 12*s.*

Also, AN EDITION TO BE COMPLETED in 20 Monthly Parts. Price 4*s.* 6*d.* each. Parts 1 to 11 *now ready.*

AN 8VO. EDITION, without the Quotations, 15*s.* Half-russia, 20*s.* Russia, 24*s.*

"It is an admirable addition to our Lexicography, supplying a great desideratum, as exhibiting the biography of each word—its birth, parentage and education, the changes that have befallen it, the company it has kept, and the connexions it has formed—by rich series of quotations, all in chronological order. This is such a Dictionary as perhaps no other language could ever boast."—*Quarterly Review.*

Dr. Richardson on the Study of Language: an Exposition of Horne Tooke's Diversions of Purley. Fcap. 8vo. 4*s.* 6*d.*

The Library of English Worthies.

A Series of reprints of the best Authors carefully edited and collated with the Early Copies, and handsomely printed by Whittingham in Octavo.

SPENSER'S Complete Works; with Life, Notes, and Glossary, by John Payne Collier, Esq., F.S.A. 5 vols. 3*l.* 15*s.* Antique calf, 6*l.* 6*s.*

Herbert's Poems and Remains; with S. T. Coleridge's Notes, and Life by Izaak Walton. Revised, with additional Notes, by Mr. J. Yeowell. 2 vols. 1*l.* 1*s.* Morocco, antique calf or morocco, 2*l.* 2*s.*

Bishop Butler's Analogy of Religion; with Analytical Index, by the Rev. Edward Steere, LL.D. 12*s.* Antique calf, 1*l.* 1*s.*

"The present edition has been furnished with an Index of the Texts of Scripture quoted, and an Index of Words and Things considerably fuller than any hitherto published."—*Editor's Preface.*

Bishop Jeremy Taylor's Rule and Exercises of Holy Living and Dying. 2 vols. 1*l.* 1*s.* Morocco, antique calf or morocco, 2*l.* 2*s.*

Gower's Confessio Amantis, with Life by Dr. Pauli, and a Glossary. 3 vols. 2*l.* 2*s.* Antique calf, 3*l.* 6*s.* Only a limited number of Copies printed.

This important work is so scarce that it can seldom be met with even in large libraries. It is wanting in nearly every collection of English Poetry.

Uniform with the above.

The Physical Theory of Another Life. By Isaac Taylor, Esq. Author of "Logic in Theology," "Ultimate Civilization, &c." *New Edition.* 10*s.* 6*d.* Antique calf, 21*s.*

HISTORY of England, from the Invasion of Julius Cæsar to the end of the Reign of George II., by Hume and Smollett. With the Continuation, to the Accession of Queen Victoria, by the Rev. T. S. Hughes, B.D. late Canon of Peterborough. *New Edition*, containing Historical Illustrations, Autographs, and Portraits, copious Notes, and the Author's last Corrections and Improvements. In 18 vols. crown 8vo. 4*s.* each.

Vols. I. to VI. (Hume's portion), 1*l.* 4*s.*
Vols. VII. to X. (Smollett's ditto), 16*s.*
Vols. XI. to XVIII. (Hughes's ditto), 1*l.* 12*s.*

History of England, from the Accession of George III. to the Accession of Queen Victoria. By the Rev. T. S. Hughes, B.D. *New Edition*, almost entirely re-written. In 7 vols. 8vo. 3*l.* 13*s.* 6*d.*

The Aldine Edition of the British Poets.

The Publishers have been induced, by the scarcity and increasing value of this admired Series of the Poets, to prepare a New Edition, very carefully corrected, and improved by such additions as recent literary research has placed within their reach.

The general principle of Editing which has been adopted is *to give the entire Poems of each author in strict conformity with the Edition which received his final revision, to prefix a Memoir,* and *to add such notes as may be necessary to elucidate the sense of obsolete words or explain obscure allusions.* Each author will be placed in the hands of a competent editor specially acquainted with the literature and bibliography of the period.

Externally this new edition will resemble the former, but with some improvements. It will be elegantly printed by Whittingham, on toned paper manufactured expressly for it; and a highly-finished portrait of each author will be given.

The *Aldine Edition of the British Poets* has hitherto been the favourite Series with the admirers of choice books, and every effort will be made to increase its claims as a comprehensive and faithful mirror of the poetic genius of the nation.

AKENSIDE'S Poetical Works, with Memoir by the Rev. A. Dyce, and additional Letters, carefully revised. 5*s*. Morocco, or antique morocco, 10*s*. 6*d*.

Collins's Poems, with Memoir and Notes by W. Moy Thomas, Esq. 3*s*. 6*d*. Morocco, or antique morocco, 8*s*. 6*d*.

Gray's Poetical Works, with Notes and Memoir by the Rev. John Mitford. 5*s*. Morocco, or antique morocco, 10*s*. 6*d*.

Kirke White's Poems, with Memoir by Sir H. Nicolas, and additional notes. Carefully revised. 5*s*. Morocco, or antique morocco, 10*s*. 6*d*.

Shakespeare's Poems, with Memoir by the Rev. A. Dyce. 5*s*. Morocco, or antique morocco, 10*s*. 6*d*.

Young's Poems, with Memoir by the Rev. John Mitford, and additional Poems. 2 vols. 10*s*. Morocco, or antique morocco, 1*l*. 1*s*.

Thomson's Poems, with Memoir by Sir H. Nicolas, annotated by Peter Cunningham, Esq., F.S.A., and additional Poems, carefully revised. 2 vols. 10*s*. Morocco, or antique morocco, 1*l*. 1*s*.

Thomson's Seasons, and Castle of Indolence, with Memoir. 6*s*. Morocco, or antique morocco, 11*s*. 6*d*.

Dryden's Poetical Works, with Memoir by the Rev. R. Hooper, F.S.A. Carefully revised. 5 vols. [*In the Press.*

Cowper's Poetical Works, including his Translations. Edited, with Memoir, by John Bruce, Esq., F.S.A. 3 vols. [*In the Press.*

Uniform with the Aldine Edition of the Poets.

The Works of Gray, edited by the Rev. John Mitford. With his Correspondence with Mr. Chute and others, Journal kept at Rome, Criticism on the Sculptures, &c. *New Edition.* 5 vols. 1*l.* 5*s.*

The Temple and other Poems. By George Herbert, with Coleridge's Notes. *New Edition.* 5*s.* Morocco, antique calf or morocco, 10*s.* 6*d.*

Vaughan's Sacred Poems and Pious Ejaculations, with Memoir by the Rev. H. F. Lyte. *New Edition.* 5*s.* Antique calf or morocco, 10*s.* 6*d.* *Large Paper,* 7*s.* 6*d.* Antique calf, 14*s.* Antique morocco, 15*s.*

"Preserving all the piety of George Herbert, they have less of his quaint and fantastic turns, with a much larger infusion of poetic feeling and expression."—*Lyte.*

Bishop Jeremy Taylor's Rule and Exercises of Holy Living and Holy Dying. 2 vols. 2*s.* 6*d.* each. Morocco, antique calf or morocco, 7*s.* 6*d.* each. In one volume, 5*s.* Morocco, antique calf or morocco, 10*s.* 6*d.*

Bishop Butler's Analogy of Religion; with Analytical Introduction and copious Index, by the Rev. Dr. Steere. 6*s.* Antique calf, 11*s.* 6*d.*

Bishop Butler's Sermons and Remains; with Memoir, by the Rev. E. Steere, LL.D. 6*s.*

*** This volume contains some additional remains, which are copyright, and render it the most complete edition extant.

Bishop Butler's Complete Works; with Memoir by the Rev. Dr. Steere. 2 vols. 12*s.*

Bacon's Advancement of Learning. Edited, with short Notes, by the Rev. G. W. Kitchin, M.A., Christ Church, Oxford. 6*s.*; antique calf, 11*s.* 6*d.*

Bacon's Essays; or, Counsels Civil and Moral, with the Wisdom of the Ancients. With References and Notes by S. W. Singer, F.S.A. 5*s.* Morocco, or antique calf, 10*s.* 6*d.*

Bacon's Novum Organum. Newly translated, with short Notes, by the Rev. Andrew Johnson, M.A. 6*s.* Antique calf, 11*s.* 6*d.*

Locke on the Conduct of the Human Understanding; edited by Bolton Corney, Esq., M. R. S. L. 3*s.* 6*d.* Antique calf, 8*s.* 6*d.*

"I cannot think any parent or instructor justified in neglecting to put this little treatise into the hands of a boy about the time when the reasoning faculties become developed."—*Hallam.*

Ultimate Civilization. By Isaac Taylor, Esq. 6*s.*

Logic in Theology, and other Essays. By Isaac Taylor, Esq. 6*s.*

The Thoughts of the Emperor M. Aurelius Antoninus. Translated by George Long. 6*s.*

The Schole Master. By Roger Ascham. Edited, with copious Notes and a Glossary, by the Rev. J. E. B. Mayor, M.A. 6*s.*

DOMESTIC Life in Palestine. By M. E. Rogers. *Second Edition.* Post 8vo. 10s. 6d.

Servia and the Servians. By the Rev. W. Denton, M.A. With Illustrations. Crown 8vo. 9s. 6d.

By-Roads and Battle Fields in Picardy: with Incidents and Gatherings by the Way between Ambleteuse and Ham; including Agincourt and Crécy. By G. M. Musgrave, M.A., Illustrated. Super-royal 8vo. 16s.

The Boat and the Caravan. A Family Tour through Egypt and Syria. *New and cheaper Edition.* Fcap. 8vo. 5s. 6d.

Fragments of Voyages and Travels. By Captain Basil Hall, R.N. 1st, 2nd, and 3rd Series in 1 vol. complete. Royal 8vo. 10s. 6d.

An Old Man's Thoughts about Many Things. Being Essays on Schools, Riches, Statues, Books, Place and Power, The Final Cause, &c. Crown 8vo. 7s. 6d.

Frederick Lucas. A Biography. By C. J. Riethmüller, author of "Teuton," a Poem. Crown 8vo. 4s. 6d.

Adventures of Baron Wenceslas Wratislaw of Mitrowitz; what he saw in the Turkish Metropolis, Constantinople, experienced in his Captivity, and, after his happy return to his country, committed to writing, in the year of our Lord, 1599. Literally translated from the original Bohemian by A. H. Wratislaw, M.A. Crown 8vo. 6s. 6d.

Legends of the Lintel and the Ley. By Walter Cooper Dendy. Crown 8vo. 9s.

The Gem of Thorney Island; or, The Historical Associations of Westminster Abbey. By the Rev. J. Ridgway, M.A. Crown 8vo. 7s. 6d.

Gifts and Graces. A new Tale, by the Author of "The Rose and the Lotus." Post 8vo. 7s. 6d.

Childhood and Youth. By Count Nicola Tolstoi. Translated from the Russian by Malwida von Meysenbug. Post 8vo. 8s. 6d.

Baronscliffe; or, the Deed of other Days. By Mrs. P. M. Latham, Author of "The Wayfarers." Crown 8vo. 6s.

The Manse of Mastland. Sketches: Serious and Humorous, in the Life of a Village Pastor in the Netherlands. Translated from the Dutch by Thomas Keightley, M.A. Post 8vo. 9s.

The Leadbeater Papers: a Selection from the MSS. and Correspondence of Mary Leadbeater, containing her Annals of Ballitore, with a Memoir of the Author; Unpublished Letters of Edmund Burke; and the Correspondence of Mrs. R. Trench and Rev. G. Crabbe. *Second Edition.* 2 vols. crown 8vo. 14s.

The Home Life of English Ladies in the Seventeenth Century. By the Author of "Magdalen Stafford." *Second Edition, enlarged.* Fcap. 8vo. 6s. Calf, 9s. 6d.

The Romance and its Hero. By the Author of "Magdalen Stafford." 2 vols. Fcap. 8vo. 12s.

Magdalen Stafford. A Tale. Fcap. 8vo. 5s.

MRS. ALFRED GATTY'S POPULAR WORKS.

"Mrs. Gatty is *facile princeps* in the art of writing for the young. She is to the altered tastes of this generation almost what Miss Edgeworth was to the last. And we have the rare satisfaction of knowing that Mrs. Gatty's usefulness will not terminate with herself. Her peculiar talent is hereditary. 'Melchior's Dream' is the production of the veritable 'Aunt Judy' herself, and the very pretty illustrations which adorn it are from the pencil of another sister."—*Guardian.*

PARABLES from Nature; with Notes on the Natural History. Illustrated by W. Holman Hunt, Otto Speckter, C. W. Cope, R. A., E. Warren, W. Millais, G. Thomas, and H. Calderon. 8vo. Ornamental cloth, 10*s.* 6*d.* Antique morocco elegant, 1*l.* 1*s.*

Parables from Nature. 16mo. with Illustrations. First Series. *Eleventh Edition.* 1*s.* 6*d.* Second Series. *Sixth Edition.* 2*s.* Or the two Series in one volume. 3*s.* 6*d.* Third Series (Red Snow and other Parables). *Second Edition.* 2*s.* Fourth Series. [*In the press.*

orlds not Realized. 16mo. *Third Edition.* 2*s.*

Proverbs Illustrated. 16mo. with Illustrations. 3*rd Edition.* 2*s.*

*** *These little works have been found useful for Sunday reading in the family circle, and instructive and interesting to school children.*

Aunt Judy's Tales. Illustrated by Clara S. Lane. Fcap. 8vo. *Fourth Edition.* 3*s.* 6*d.*

Aunt Judy's Letters. Illustrated by Clara S. Lane. Fcap. 8vo. 3*s.* 6*d.*

The Human Face Divine, and other Tales. With Illustrations by C. S. Lane. Fcap. 8vo. 3*s.* 6*d.*

The Fairy Godmothers and other Tales. *Fourth Edition.* Fcap. 8vo. with Frontispiece. 2*s.* 6*d.*

Legendary Tales. With Illustrations by Phiz. Fcap. 8vo. 5*s.*

The Poor Incumbent. Fcap. 8vo. Sewed, 1*s.* Cloth, 1*s.* 6*d.*

The Old Folks from Home; or, a Holiday in Ireland. *Second Edition.* Post 8vo. 7*s.* 6*d.*

Melchior's Dream, and other Tales. By J. H. G. Edited by Mrs. Gatty. Illustrated. Fcap. 8vo. 3*s.* 6*d.*

BY THE LATE MRS. WOODROOFFE.

COTTAGE Dialogues. *New Edition.* 12mo. 4*s.* 6*d.*

Michael Kemp, the Happy Farmer's Lad. 8*th Edition.* 12mo. 4*s.*

A Sequel to Michael Kemp. *New Edition.* 12mo. 6*s.* 6*d.*

THE Adventures of a Little French Boy. With 50 Illustrations. Crown 8vo. Cloth, gilt edges. 7*s.* 6*d.*

The Life and Adventures of Robinson Crusoe. By Daniel Defoe. With 100 Illustrations by E. H. Wehnert. Uniform with the above. Crown 8vo. Cloth, gilt edges. 7*s.* 6*d.*

Andersen's Tales for Children. Translated by A. Wehnert. With 105 Illustrations by E. H. Wehnert, W. Thomas, and others. Uniform with the above. Crown 8vo. Cloth, gilt edges. 7*s.* 6*d.*

Among the Tartar Tents; or, the Lost Fathers. A Tale. By Anne Bowman, Author of "Esperanza," "The Boy Voyagers," &c. With Illustrations. Crown 8vo. 5*s.*

Little Maggie and her Brother. By Mrs. G. Hooper, Author of "Recollections of Mrs. Anderson's School," "Arbell," &c. With a Frontispiece. Fcap. 8vo. 2*s.* 6*d.*

Church Stories. Edited by the Rev. J. E. Clarke. Crown 8vo. 2*s.* 6*d.*

Cavaliers and Round Heads. By J. G. Edgar, Author of "Sea Kings and Naval Heroes." Illustrated by Amy Butts. Fcap. 8vo. 5*s.*

Sea-Kings and Naval Heroes. A Book for Boys. By J. G. Edgar. With Illustrations by C. K. Johnson and C. Keene. Fcap. 8vo. 5*s.*

The White Lady and Undine, translated from the German by the Hon. C. L. Lyttelton. With numerous Illustrations. Fcap. 8vo. 5*s.* Or, separately, 2*s.* 6*d.* each.

The Lights of the Will o' the Wisp. Translated by Lady Maxwell Wallace. With a coloured Frontispiece. Imperial 16mo. Cloth, gilt edges, 5*s.*

The Life of Christopher Columbus, in Short Words. By Sarah Crompton. Super royal 16mo. 2*s.* 6*d.* Also an Edition for Schools, 1*s.*

The Life of Martin Luther, in Short Words. By the same Author. Super royal 16mo. 1*s.* 6*d.* Stiff cover, 1*s.*

Guessing Stories; or, the Surprising Adventures of the Man with the Extra Pair of Eyes. A Book for Young People. By the Rev. Philip Freeman. Imperial 16mo. Cloth, gilt edges, 3*s.*

Redfield; or, a Visit to the Country. A Story for Children. With Four Illustrations by John Absolon. Super royal 16mo. 2*s.* 6*d.* Coloured, 3*s.* 6*d.*

Giles Witherne; or, The Reward of Disobedience. A Village Tale for the Young. By the Rev. J. P. Parkinson, D.C.L. *Sixth Edition.* Illustrated by the Rev. F. W. Mann. Super-royal 16mo. 1*s.* Cloth, gilt edges, 2*s.* 6*d.*

The Disorderly Family; or, the Village of R * * * *. A Tale for Young Persons. In Two Parts. By a Father. 6*d.*; Cloth, gilt edges, 1*s.*

Nursery Tales. By Mrs. Motherly. With Illustrations by C. S. Lane. Imperial 16mo. 2*s.* 6*d.* Coloured, gilt edges, 3*s.* 6*d.*

Nursery Poetry. By Mrs. Motherly. With Eight Illustrations by C. S. Lane. Imperial 16mo. 2*s.* 6*d.* Coloured, gilt edges, 3*s.* 6*d.*

A Poetry Book for Children. Illustrated with Thirty-seven highly-finished Engravings, by C. W. Cope, R. A., Helmsley, Palmer, Skill, Thomas, and H. Weir. *New Edition.* Crown 8vo. 2*s.* 6*d.*

Nursery Carols. Illustrated with 120 Pictures. By Ludwig Ricther and Oscar Pletsch. Imperial 16mo. Ornamental Binding. 3*s.* 6*d.* Coloured, 6*s.*

Poetry for Play-Hours. By Gerda Fay. With Eight large Illustrations. Imperial 16mo. 3*s.* 6*d.* Coloured, gilt edges, 4*s.* 6*d.*

Very Little Tales for Very Little Children In single Syllables of *Four* and *Five* letters. *New Edition.* Illustrated. 2 vols. 16mo. 1*s.* 6*d.* each, or in 1 vol. 3*s.*

Progressive Tales for Little Children. In words of *One* and *Two* Syllables. Forming the sequel to "Very Little Tales." *New Edition.* Illustrated. 2 vols. 16mo. 1*s.* 6*d.* each, or in 1 vol. 3*s.*

Karl and the Six Little Dwarfs. By Julia Goddard. Illustrated. 16mo. 2*s.* 6*d.*

Charades, Enigmas, and Riddles. Collected by a Cantab. *Fourth Edition, enlarged.* Illustrated. Fcap. 8vo. 2*s.* 6*d.*

The Children's Picture Book Series.

Written expressly for Young People, super-royal 16mo.

Cloth, gilt edges, price 5s. each.

BIBLE Picture Book. Eighty Illustrations. (Coloured, 9*s.*)

Scripture Parables and Bible Miracles. Thirty-two Illustrations. (Coloured, 7*s.* 6*d.*)

English History. Sixty Illustrations. (Coloured, 9*s.*)

Good and Great Men. Fifty Illustrations. (Coloured, 9*s.*)

Useful Knowledge. One Hundred and Thirty Figures.

Cloth, red edges, price 2s. 6d. each. (Coloured, gilt edges, 3s. 6d.)

Scripture Parables. By Rev. J. E. Clarke. 16 Illustrations.

Bible Miracles. By Rev. J. E. Clarke, M.A. 16 Illustrations.

The Life of Joseph. Sixteen Illustrations.

Bunyan's Pilgrim's Progress. Sixteen Illustrations.

CLARK'S Introduction to Heraldry.—Containing Rules for Blazoning and Marshalling Coats of Armour—Dictionary of Terms—Orders of Knighthood explained—Degrees of the Nobility and Gentry—Tables of Precedency; 48 Engravings, including upwards of 1,000 Examples, and the Arms of numerous Families. *Sixteenth Edition improved.* Small 8vo. 7s. 6d. Coloured, 18s.

Book of Family Crests and Mottoes, with *Four Thousand Engravings* of the Crests of the Peers, Baronets, and Gentry of England and Wales, and Scotland and Ireland. A Dictionary of Mottos, &c. *Tenth Edition, enlarged.* 2 vols. small 8vo. 1l. 4s.

"Perhaps the best recommendation to its utility and correctness (in the main) is, that it has been used as a work of reference in the Heralds College. No wonder it sells."—*Spectator.*

The Architectural History of Chichester Cathedral, with an Introductory Essay on the Fall of the Tower and Spire. By the Rev. R. Willis, M.A., F.R.S., &c.—Of Boxgrove Priory, by the Rev. J. L. Petit, M.A., F.S.A.—And of Shoreham Collegiate Church, together with the Collective Architectural History of the foregoing buildings, as indicated by their mouldings, by Edmund Sharpe, M.A., F.R.I.B.A. Illustrated by one hundred Plates, Diagrams, Plans and Woodcuts. Super-royal 4to. 1l. 10s.

Architectural Studies in France. By the Rev. J. L. Petit, M.A., F.S.A. With Illustrations from Drawings by the Author and P. H. Delamotte. Imp. 8vo. 2l. 2s.

Remarks on Church Architecture. With Illustrations. By the Rev. J. L. Petit, M.A. 2 vols. 8vo. 1l. 1s.

A Few Notes on the Temple Organ. By Edmund Macrory, M.A. *Second Edition.* Super-royal 16mo. Half morocco, Roxburgh, 3s. 6d.

Scudamore Organs, or Practical Hints respecting Organs for Village Churches and small Chancels, on improved principles. By the Rev. John Baron, M.A., Rector of Upton Scudamore, Wilts. With Designs by G. E. Street, F.S.A. *Second Edition, revised and enlarged.* 8vo. 6s.

The Bell; its Origin, History, and Uses. By Rev. A. Gatty. 3s.

Practical Remarks on Belfries and Ringers. By the Rev. H. T. Ellacombe, M.A., F.A.S., Rector of Clyst St. George, Devonshire. *Second Edition,* with an Appendix on Chiming. Illustrated. 8vo. 3s.

Engravings of Unedited or Rare Greek Coins. With Descriptions. By General C. R. Fox. 4to. Part I, Europe. Part II, Asia and Africa. 7s. 6d. each.

Proceedings of the Archæological Institute at Newcastle, in 1853. With Numerous Engravings. 2 vols. 8vo. 2l. 2s.

A Handbook for Visitors to Cambridge. By Norris Deck. With 8 Steel Engravings, 97 Woodcuts, and a Map. Crown 8vo. 5s.

Canterbury in the Olden Time: from the Municipal Archives and other Sources. By John Brent, F.S.A. With Illustrations. 5s.

Whirlwinds and Dust-Storms of India. By P. F. H. Baddeley. Large 8vo. With Illustrations, 8s. 6d.; without Illustrations, 3s.

Two Transparent Wind Cards in Horn, adapted to the Northern and Southern Hemispheres, for the use of Sailors. 2s.

WEBSTER'S Complete Dictionary of the English Language. *New Edition,* revised and greatly enlarged, by CHAUNCEY A. GOODRICH, Professor in Yale College. 4to. (1624 pp.) 1*l.* 11*s.* 6*d.*; half calf, 2*l.*; calf, or half russia, 2*l.* 2*s.*; russia, 2*l.* 10*s.*

Though the circulation of Dr. Webster's celebrated Dictionary, in its various forms, in the United States, in England, and in every country where the English Language is spoken, may be counted by hundreds of thousands, it is believed that there are many persons to whom the book is yet unknown, and who, if seeking for a Dictionary which should supply all reasonable wants, would be at a loss to select one from the numerous competitors in the field.

In announcing this New Edition, the Proprietors desire to call attention to the features which distinguish it, and to put before those who are in want of such a book, the points in which it excels all other Dictionaries, and which render it the best that has as yet been issued for the practical purposes of daily use:—

1. Accuracy of Definition. 2. Pronunciation intelligibly marked. 3. Completeness. 4. Etymology. 5. Obsolete Words. 6. Uniformity in the Mode of Spelling. 7. Quotations. 8. Cheapness.

With the determination that the superiority of the work shall be fully maintained, and that it shall keep pace with the requirements of the age and the universal increase of education, the Proprietors have added to this New Edition, under the editorship of Professor Goodrich,—

A Table of Synonyms. An Appendix of New Words. Table of Quotations, Words, Phrases, &c.

Tables of Interest, enlarged and Improved; calculated at Five per Cent.; Showing at one view the Interest of any Sum, from £1 to £365: they are also carried on by hundreds to £1,000, and by thousands to £10,000, from one day to 365 days. To which are added, Tables of Interest, from one to 12 months, and from two to 13 years. Also Tables for calculating Commission on Sales of Goods or Banking Accounts, from ⅛ to 5 per Cent., with several useful additions, among which are Tables for calculating Interest on large sums for 1 day, at the several rates of 4 and 5 per Cent. to £100,000,000. By Joseph King, of Liverpool. *24th Edition.* With a Table showing the number of days from any one day to any other day in the Year. 8vo. 1*l.* 1*s.*

The Housekeeping Book, or Family Ledger. An Improved Principle, by which an exact Account can be kept of Income and Expenditure; suitable for any Year, and may be begun at any time. With Hints on Household Management, Receipts, &c. By Mrs. Hamilton. 8vo. Cloth, 1*s.* 6*d.* sewed, 1*s.*

The Executor's Account Book, with short Practical Instructions for the guidance of Executors. By a Solicitor. Folio. 4*s.*

NIGHTINGALE Valley; a Collection of Choice Lyrics and Short Poems. From the time of Shakespeare to the present day. Edited by William Allingham. Fcap. 8vo. 5*s.*; mor., antique calf or mor., 10*s.* 6*d.*

Legends and Lyrics, by Adelaide Anne Procter. *Seventh Edition.* Fcap. 5*s.* Antique or best plain morocco, 10*s.* 6*d.*

——— *Second Series. Third Edition.* Fcap. 8vo. 5*s.*; antique or best plain morocco, 10*s.* 6*d.*

Latin Translations of English Hymns. By Charles Buchanan Pearson, M.A., Rector of Knebworth. Fcap. 8vo. 5*s.*

Verses for Holy Seasons. By C. F. Alexander. Edited by the Very Rev. W. F. Hook, D.D. *4th Edition.* Fcap. 3s. 6d.; morocco, antique calf or morocco, 8s. 6d.

The Legend of the Golden Prayers, and other Poems. By the Same Author. Fcap. 8vo. 5s.; antique or best plain morocco, 10s. 6d.

Ballads and Songs. By Bessie Rayner Parkes. Fcap. 5s

The Story of Queen Isabel, and other Verses. By M. S. Fcap. 8vo. 3s. 6d.

Love and Mammon, and other Poems. By. F. S. Wyvill, Author of "Pansies." Fcap. 8vo. 5s.

The Frithiof Saga. A Poem. Translated from the Norwegian. By the Rev. R. Mucklestone, M.A., Rector of Dinedor. Cr. 8vo. 7s. 6d.

Saul, a Dramatic Poem; Elizabeth, an Historical Ode; and other Poems. By William Fulford, M.A. Fcap. 8vo. 5s.

Lays and Poems on Italy. By F. A. Mackay. Fcap. 8vo. 5s.

Poems from the German. By Richard Garnett, Author of "Io in Egypt, and other Poems." Fcap. 8vo. 3s. 6d.

Io in Egypt, and other Poems. By R. Garnett. Fcap. 8vo. 5s.

The Monks of Kilcrea, and other Poems. *3rd Edition.* Post. 7s. 6d.

Teuton. A Poem. By C. J. Riethmüller. Crown 8vo. 7s. 6d.

Dryope, and other Poems. By T. Ashe. Fcap. 8vo. 6s.

Wild Thyme. By E. M. Mitchell. Fcap. 8vo. 5s.

Lyrics and Idylls. By Gerda Fay. Fcap. 8vo. 4s.

David Mallet's Poems. With Notes and Illustrations by F. Dinsdale, LL.D., F.S.A. *New Edition.* Post 8vo. 10s. 6d.

Ballads and Songs of Yorkshire. Transcribed from private MSS., rare Broadsides, and scarce Publications; with Notes and a Glossary. By C. J. D. Ingledew, M.A., Ph.D., F.G.H.S., author of "The History of North Allerton." Fcap. 8vo. 6s.

Percy's Reliques of Ancient English Poetry. 3 vols. sm. 8vo. 15s. Half-bound, 18s. Antique calf, or morocco, 1l. 11s. 6d.

The Book of Ancient Ballad Poetry of Great Britain, Historical, Traditional and Romantic: with Modern Imitations, Translations, Notes and Glossary, &c. *New and Improved Edition.* 8vo. Half-bound, 14s. Antique morocco, 21s.

The Promises of Jesus Christ. Illuminated by Albert H. Warren, *Second Edition.* Ornamental cloth, 15s. Antique morocco elegant, 21s.

Christmas with the Poets: a Collection of English Poetry relating to the Festival of Christmas. Illustrated by Birket Foster, and with numerous initial letters and borders beautifully printed in gold and colours by Edmund Evans. *New and improved Edition.* Super royal 8vo. Ornamental binding, 21s. Antique morocco, 31s. 6d.

ATHENÆ Cantabrigienses. By C. H. Cooper, F.S.A., and Thompson Cooper. Volume I. 1500—1585. 8vo. 18*s*. Vol. II. 1586—1609. 8vo. 18*s*.

This work, in illustration of the biography of notable and eminent men who have been members of the University of Cambridge, comprehends notices of:—1. Authors. 2. Cardinals, archbishops, bishops, abbots, heads of religious houses and other church dignitaries. 3. Statesmen, diplomatists, military and naval commanders. 4. Judges and eminent practitioners of the civil or common law. 5. Sufferers for religious or political opinions. 6. Persons distinguished for success in tuition. 7. Eminent physicians and medical practitioners. 8. Artists, musicians, and heralds. 9. Heads of colleges, professors, and principal officers of the university. 10. Benefactors to the university and colleges, or to the public at large.

The Early and Middle Ages of England. By C. H. Pearson, M.A., Fellow of Oriel College, Oxford, and Professor of Modern History, King's College, London. 8vo. 12*s*.

Choice Notes from "Notes and Queries," by the Editor. Fcap. 8vo. 5*s*. each.
VOL. I.—HISTORY. VOL. II.—FOLK LORE.

Master Wace's Chronicle of the Conquest of England. Translated from the Norman by Sir Alexander Malet, Bart., H.B.M. Plenipotentiary, Frankfort. With Photograph Illustrations of the Bayeaux Tapestry. Medium 4to. Half-morocco, Roxburgh, 2*l*. 2*s*.

The Prince Consort's Addresses on Different Public Occasions. Beautifully printed by Whittingham. 4to. 10*s*. 6*d*.

Life and Books; or, Records of Thought and Reading. By J. F. Boyes, M.A. Fcap. 8vo. 5*s*.; calf, 8*s*. 6*d*.

Life's Problems. By Sir Rutherford Alcock, K. C. B. *Second Edition*, revised and enlarged. Fcap. 5*s*.

Parliamentary Short-Hand (Official System). By Thompson Cooper. Fcap. 8vo. 2*s*. 6*d*.

This is the system *universally practised by the Government Official Reporters*. It has many advantages over the system ordinarily adopted, and has hitherto been inaccessible, except in a high-priced volume.

English Retraced; or, Remarks, Critical and Philological, founded on a Comparison of the Breeches Bible with the English of the present day. Crown 8vo. 5*s*.

The Pleasures of Literature. By R. Aris Willmott, M.A. *Fifth Edition*, enlarged. Fcap. 8vo. 5*s*. Morocco, 10*s*. 6*d*.

Hints and Helps for Youths leaving School. By the Rev. J. S. Gilderdale, M.A. Fcap. 8vo. 5*s*. Calf, 8*s*. 6*d*.

Hints for Pedestrians, Practical and Medical. By G. C. Watson, M.D. *Third Edition, enlarged*. Fcap. 8vo. 2*s*. 6*d*.

Hints to Maid Servants in Small Households, on Manners, Dress, and Duties. By Mrs. Motherly. Fcap. 8vo. 1*s.* 6*d.*

A Wife's Home Duties; containing Hints to inexperienced Housekeepers. Fcap. 8vo. 2*s.* 6*d.*

Geology in the Garden: or, The Fossils in the Flint Pebbles. With 106 Illustrations. By the Rev. Henry Eley, M.A.. Fcap. 8vo. 6*s.*

British Beetles. Transferred in 259 plates from Curtis's "British Entomology;" with Descriptions by E. W. Janson, Esq., Secretary of the Entomological Society. 4to. 18*s.* Coloured, 1*l.* 11*s.* 6*d.* [*Ready.*

Halcyon: or Rod-Fishing with Fly, Minnow, and Worm. To which is added a short and easy method of dressing Flies, with a description of the materials used. By Henry Wade, Honorary Secretary to the Wear Valley Angling Association. With 8 Coloured Plates, containing 117 Specimens of natural and artificial Flies, Materials, &c., and 4 Plates illustrating Fishes, Baiting, &c. Cr. 8vo. 7*s.* 6*d.*

A Handy Book of the Chemistry of Soils: Explanatory of their Composition, and the Influence of Manures in ameliorating them, with Outlines of the various Processes of Agricultural Analysis. By John Scoffern, M.B. Crown 8vo. 4*s.* 6*d.*

Flax and its Products in Ireland. By William Charley, J. P., Juror and Reporter Class XIV, Great Exhibition 1851; also appointed in 1862 for Class XIX. With a Frontispiece. Crown 8vo. 5*s.*

The Odes and Carmen Sæculare of Horace. Translated into English Verse by John Conington, M.A., Corpus Professor of Latin in the University of Oxford. *Second Edition.* Fcap. 8vo. Roxburgh binding. 5*s.* 6*d.*

SERMONS.

PARISH SERMONS. By the Rev. M. F. Sadler, M.A., Vicar of Bridgwater. Author of "The Second Adam and the New Birth." Fcap. 8vo. Vol. I, Advent to Trinity; Vol. II, Trinity to Advent. 7*s.* 6*d.* each.

Twenty-four Sermons on Christian Doctrine and Practice, and on the Church, By C. J. Blomfield, D.D., late Lord Bishop of London. (*Hitherto unpublished.*) 8vo. 10*s.* 6*d.*

King's College Sermons. By the Rev. E. H. Plumptre, M.A., Divinity Professor. Fcap. 8vo. 2*s.* 6*d.*

Sermons preached in Westminster. By the Rev. C. F. Secretan, M.A., Incumbent of Holy Trinity, Vauxhall-Bridge Road. Fcap. 8vo. 6*s.*

Sermons. By the Rev. A. Gatty, D.D., Vicar of Ecclesfield. 12mo. 8*s.*

Twenty Plain Sermons for Country Congregations and Family Reading. By the Rev. A. Gatty, D.D., Vicar of Ecclesfield. Fcap. 5*s.*

Sermons to a Country Congregation—Advent to Trinity. By the Rev. Hastings Gordon, M.A. 12mo. 6*s.*

Sermons Suggested by the Miracles of our Lord and Saviour Jesus Christ. By the Very Rev. Dean Hook. 2 vols. Fcap. 8vo. 12*s.*

Five Sermons Preached before the University of Oxford. By the Very Rev. W. F. Hook, D.D., Dean of Chichester. *Third Edition.* 3*s.*

The Last Days of our Lord's Ministry: a Course of Lectures on the principal events of Passion Week. By Walter Farquhar Hook, D.D., F.R.S., Dean of Chichester. *New Edition.* Fcap. 8vo. 3*s.* 6*d.*

Sermons, chiefly Practical. By the Rev. T. Nunns, M.A. Edited by the Very Rev. W. F. Hook, D.D., Dean of Chichester. Fcap. 8vo. 6*s.*

Sermons on Popular Subjects, preached in the Collegiate Church, Wolverhampton. By the Rev. Julius Lloyd, M. A. 8vo. 4*s.* 6*d.*

The Prodigal Son. Sermons by W. R. Clark, M.A., Vicar of Taunton, S. Mary Magdalene. Fcap. 8vo. 2*s.* 6*d.*

The Redeemer: a Series of Sermons on Certain Aspects of the Person and Work of our Lord Jesus Christ. By W. R. Clark, M.A., Vicar of Taunton. Fcap. 8vo. 5*s.*

The Fulness of the Manifestation of Jesus Christ; being a Course of Epiphany Lectures. By Hilkiah Bedford Hall, B.C.L., Afternoon Lecturer of the Parish Church, Halifax, Author of "A Companion to the Authorized Version of the New Testament. Fcap. 8vo. 2*s.*

Parochial Sermons. By the Rev. D. G. Stacy, Vicar of Hornchurch, Essex. Fcap. 8vo. 5*s.*

Plain Parochial Sermons. By the Rev. C. F. C. Pigott, B.A., late Curate of St. Michael's, Handsworth. Fcap. 8vo. 6*s.*

Our Privileges, Responsibilities, and Trials. By the Rev. E. Phillips, M.A. Fcap. 8vo. 5*s.*

Sermons, Preached in the Parish Church of Godalming, Surrey, by the Rev. E. J. Boyce, M.A., Vicar. *Second Edition.* Fcap. 8vo. 6*s.*

Life in Christ. By the Rev. J. Llewellyn Davies, M.A., Rector of Christ Church, Marylebone. Fcap. 8vo. 5*s.*

The Church of England; its Constitution, Mission, and Trials. By the Rt. Rev. Bishop Broughton. Edited, with a Prefatory Memoir, by the Ven. Archdeacon Harrison. 8vo. 10*s.* 6*d.*

Plain Sermons, Addressed to a Country Congregation. By the late E. Blencowe, M.A. 1st and 3rd Series, fcap. 8vo. 7*s.* 6*d.* each.

Missionary Sermons preached at Hagley. Fcap. 3*s.* 6*d.*

The Sufficiency of Christ. Sermons preached during the Reading Lenten Mission of 1860. Fcap. 8vo. 2*s.* 6*d.*

Westminster Abbey Sermons for the Working Classes. Fcap. *Authorized Edition.* 1858. 2*s.*: 1859. 2*s.* 6*d.*

Sermons preached at St. Paul's Cathedral. *Authorized Edition.* 1859. Fcap. 8vo. 2*s.* 6*d.*

DAILY Readings for a Year, on the Life of Our Lord and Saviour Jesus Christ. By the Rev. Peter Young, M.A. *Third Edition*, improved. 2 vols. 8vo. 1*l.* 1*s.* Antique calf, 1*l.* 16*s.* Morocco, Hayday, 2*l.*

Short Sunday Evening Readings, Selected and Abridged from various Authors by the Dowager Countess of Cawdor. In large type. 8vo. 5*s.*

A Commentary on the Gospels for the Sundays and other Holy Days of the Christian Year. By the Rev. W. Denton, A.M., Worcester College, Oxford, and Incumbent of St. Bartholomew's, Cripplegate. 3 vols. 8vo. 42*s.* Vol. I. Advent to Easter, 15*s.* Vol. II. Easter to the Sixteenth Sunday after Trinity, 14*s.* Vol. III. Seventeenth Sunday after Trinity to Advent, and other Holy Days, 13*s.*

A Commentary, Critical, Exegetical, and Doctrinal, on St. Paul's Epistle to the Galatians: with a revised Translation. By George John Gwynne, A.B., Ex-Schol. T.C.D., Rector and Vicar of Wallstown, Diocese of Cloyne. 8vo. 12*s.*

The Second Adam, and the New Birth; or, the Doctrine of Baptism as contained in Holy Scripture. By the Rev. M. F. Sadler, M.A. Vicar of Bridgewater, Author of "The Sacrament of Responsibility." *Third Edition*, greatly enlarged. Fcap. 8vo. 4*s.* 6*d.*

The Sacrament of Responsibility; or, Testimony of the Scripture to the teaching of the Church on Holy Baptism, with especial reference to the Cases of Infants, and Answers to Objections. *Sixth Edition.* 6*d.*

Popular Illustrations of some Remarkable Events recorded in the Old Testament. By the Rev. J. F. Dawson, LL.B., Rector of Toynton. Post 8vo. 8*s.* 6*d.*

The Acts and Writings of the Apostles. By C. Pickering Clarke, M.A. Post 8vo. Vol. I., with Map., 7*s.* 6*d.*

A Manual for Communion Classes and Communicant Meetings. Addressed specially to the Parish Priests and Deacons of the Church of England. By C. Pickering Clarke, M.A. Fcap. 8vo. 3*s.* 6*d.*

Memoir of a French New Testament, in which the Mass and Purgatory are found in the Sacred Text; together with Bishop Kidder's "Reflections" on the same. By Henry Cotton, D.C.L., Archdeacon of Cashel. *Second Edition, enlarged.* 8vo. 3*s.* 6*d.*

The Spirit of the Hebrew Poetry. By Isaac Taylor, Esq., Author of "The Natural History of Enthusiasm," "Ultimate Civilization," &c. 8vo. 10*s.* 6*d.*

The Wisdom of the Son of David: an Exposition of the First Nine Chapters of the Book of Proverbs. Fcap. 8vo. 5*s.*

A Companion to the Authorized Version of the New Testament: being Explanatory Notes, together with Explanatory Observations and an Introduction. By the Rev. H. B. Hall, B.C.L. *Second and cheaper Edition*, revised and enlarged. Fcap. 8vo. 3*s.* 6*d.*

Readings on the Morning and Evening Prayer and the Litany. By J. S. Blunt. *Third Edition.* Fcap. 8vo. 3s. 6d.

Confirmation. By J. S. Blunt, Author of "Readings on the Morning and Evening Prayer," &c. Fcap. 8vo. 3s. 6d.

Life after Confirmation. By the same Author. 18mo. 1s.

A History of the Church of England from the Accession of James II. to the Rise of the Bangorian Controversy in 1717. By the Rev. T. Debary, M.A. 8vo. 14s.

A Treatise on Metaphysics in Connection with Revealed Religion. By the Rev. J. H. MacMahon. 8vo. 14s.

Aids to Pastoral Visitation, selected and arranged by the Rev. H. B. Browning, M.A., Curate of St. George, Stamford. *Second Edition.* Fcap. 8vo. 3s. 6d.

Remarks on Certain Offices of the Church of England, popularly termed the Occasional Services. By the Rev. W. J. Dampier. 12mo. 5s.

The Sympathy of Christ. Six Readings for the Sundays in Lent, or for the Days of the Holy Week. By the Rev. W. J. Dampier, M.A., Vicar of Coggeshall. *Second Edition.* 18mo. 2s. 6d.

Reasons of Faith; or, the Order of the Christian Argument developed and explained. By the Rev. G. S. Drew, M.A. Fcap. 8vo. 4s. 6d

Charles and Josiah; or, Friendly Conversations between a Churchman and a Quaker. Crown 8vo. 5s.

The English Churchman's Signal. By the Writer of "A Plain Word to the Wise in Heart." Fcap. 8vo. 2s. 6d.

A Plain Word to the Wise in Heart on our Duties at Church, and on our Prayer Book. *Fourth Edition.* Sewed, 1s. 6d.

The Book of Psalms (Prayer Book Version). With Short Headings and Explanatory Notes. By the Rev. Ernest Hawkins, B.D., Prebendary of St. Paul's. *Second and cheaper Edition, revised and enlarged,* Fcap. 8vo., cloth limp, red edges, 2s. 6d.

Family Prayers:—containing Psalms, Lessons, and Prayers, for every Morning and Evening in the Week. By the Rev. Ernest Hawkins, B.D., Prebendary of St. Paul's. *Eighth Edition.* Fcap. 8vo. 1s.; sewed, 9d.

Household Prayers on Scriptural Subjects, for Four Weeks. With Forms for various occasions. By a Member of the Church of England. *Second Edition, enlarged.* 8vo. 4s. 6d.

Forms of Prayer adapted to each Day of the Week. For use in Families or Households. By the Rev. John Jebb, D.D., 8vo. 2s. 6d.

Walton's Lives of Donne, Wotton, Hooker, Herbert, and Sanderson. A New Edition, to which is now added a Memoir of Mr. Isaac Walton, by William Dowling, Esq. of the Inner Temple, Barrister-at-Law. With Illustrative Notes, numerous Portraits, and other Engravings, Index, &c. Crown 8vo. 10*s.* 6*d.* Calf antique, 15*s.* Morocco, 18*s.*

The Life of Martin Luther. By H. Worsley, M.A., Rector of Easton, Suffolk. 2 vols. 8vo. 1*l.* 4*s.*

Papers on Preaching and Public Speaking. By a Wykehamist. Fcap. 8vo. 5*s.*

This volume is an enlargement and extension, with corrections, of the Papers which appeared in the "Guardian" in 1858-9.

The Speaker at Home. Chapters on Public Speaking and Reading aloud, by the Rev. J. J. Halcombe, M.A., and on the Physiology of Speech, by W. H. Stone, M.A., M.B. *Second Edition.* Fcap. 8vo. 3*s.* 6*d.*

Civilization considered as a Science in Relation to its Essence, its Elements, and its End. By George Harris, F.S.A., of the Middle Temple, Barrister at Law, Author of "The Life of Lord Chancellor Hardwicke." 8vo. 12*s.*

The Church Hymnal, (with or without Psalms.) 12mo. Large Type, 1*s.* 6*d.* 18mo. 1*s.* 32mo. for Parochial Schools, 6*d.*

This book is now in use in every English Diocese, and is the *Authorized* Book in some of the Colonial Dioceses.

Three Lectures on Archbishop Cranmer. By the Rev. C. J. Burton, M.A., Chancellor of Carlisle. 12mo. 3*s.*

Church Reading: according to the method advised by Thomas Sheridan. By the Rev. J. J. Halcombe, M.A. 8vo. 3*s.* 6*d.*

The Bishop of Worcester's Primary Charge, August, 1862. 8vo. 2*s.*

The Offertory: the most excellent way of contributing Money for Christian Purposes. By J. H. Markland, D.C.L., F.R.S., S.A. *Second Edition, enlarged,* 2*d.*

*** Messrs. Bell and Daldy are agents for the Publications of the Society for the Propagation of the Gospel in Foreign Parts.

By the Rev. J. Erskine Clarke, *of Derby.*

HEART Music, for the Hearth-Ring; the Street-Walk; the Country Stroll; the Work-Hours; the Rest-Day; the Trouble-Time. *New Edition.* 1*s.* paper; 1*s.* 6*d.* cloth limp.

The Giant's Arrows. A Book for the Children of Working People. 16mo. 6*d.*; cloth, 1*s.*

Children at Church. Twelve Simple Sermons. 2 vols. 1*s.* each; 1*s.* 6*d.* cloth, gilt; or together in 1 vol. cloth gilt, 2*s.* 6*d.*

Plain Papers on the Social Economy of the People. Fcap. 8vo. 2*s.* 6*d.*

No. 1. Recreations of the People.—No. 2. Penny Banks.—No. 3. Labourers' Clubs and Working Men's Refreshment Rooms.—No. 4. Children of the People. 6*d.* each.

The Devotional Library.

Edited by the Very Rev. W. F. Hook, D.D., Dean of Chichester.

A Series of Works, original or selected from well-known Church of England Divines, published at the lowest price, and suitable, from their practical character and cheapness, for Parochial distribution.

SHORT Meditations for Every Day in the Year. 2 vols. (1260 pages,) 32mo. Cloth, 5s.; calf, gilt edges, 9s. Calf antique, 12s.

In Separate Parts.

ADVENT to LENT, cloth, 1s.; limp calf, gilt edges, 2s. 6d.; LENT, cloth, 9d.: calf, 2s. 3d. EASTER, cloth, 9d.; calf, 2s. 3d. TRINITY, Part I. 1s.; calf, 2s. 6d. TRINITY, Part II. 1s.; calf, 2s. 6d.

*** *Large Paper Edition*, 4 vols. fcap. 8vo. large type. 14s. Morocco, 30s.

The Christian taught by the Church's Services. (490 pages), royal 32mo. Cloth, 2s. 6d.; calf, gilt edges, 4s. 6d. Calf antique, 6s.

In Separate Parts.

ADVENT TO TRINITY, cloth, 1s.; limp calf, gilt edges, 2s. 6d. TRINITY, cloth, 8d.; calf, 2s. 2d. MINOR FESTIVALS, 8d.; calf, 2s. 2d.

*** *Large Paper Edition*, Fcap. 8vo. large type. 6s. 6d. Calf antique, or morocco, 11s. 6d.

Devotions for Domestic Use. 32mo. cloth, 2s.; calf, gilt edges, 4s. Calf antique, 5s. 6d. Containing:—

The Common Prayer Book the best Companion in the Family as well as in the Temple. 3d.
Litanies for Domestic Use, 2d.
Family Prayers; or, Morning and Evening Services for every Day in the Week. By the Bishop of Salisbury; cloth, 6d.; calf, 2s.
Bishop Hall's Sacred Aphorisms. Selected and arranged with the Texts to which they refer. By the Rev. R. B. Exton, M.A.; cloth, 9d.

*** These are arranged together as being suitable for Domestic Use; but they may be had separately at the prices affixed.

Aids to a Holy Life. First Series. 32mo. Cloth, 1s. 6d.; calf, gilt edges, 3s. 6d. Calf antique, 5s. Containing:—

Prayers for the Young. By Dr. Hook, ½d.
Pastoral Address to a Young Communicant. By Dr. Hook, ½d.
Helps to Self-Examination. By W. F. Hook, D.D., ½d.
Directions for Spending One Day Well. By Archbishop Synge, ½d.
Rules for the Conduct of Human Life. By Archbishop Synge. 1d.
The Sum of Christianity, wherein a short and plain Account is given of the Christian Faith; Christian's Duty; Christian Prayer; Christian Sacrament. By C. Ellis, 1d.
Ejaculatory Prayer; or, the Duty of Offering up Short Prayers to God on all Occasions. By R. Cook. 2d.
Prayers for a Week. From J. Sorocold, 2d.
Companion to the Altar; being Prayers, Thanksgivings, and Meditations. Edited by Dr. Hook. Cloth, 6d.

*** Any of the above may be had for distribution at the prices affixed; they are arranged together as being suitable for Young Persons and for Private Devotion.

The Devotional Library continued.

Aids to a Holy Life. Second Series. 32mo. Cloth, 2*s.*; calf, gilt edges, 4*s.* Calf antique, 5*s.* 6*d.* Containing:—

Holy Thoughts and Prayers, arranged for Daily Use on each Day in the Week, 3*d.*

The Retired Christian exercised on Divine Thoughts and Heavenly Meditations. By Bishop Ken. 3*d.*

Penitential Reflections for the Holy Season of Lent, and other Days of Fasting and Abstinence during the Year. 6*d.*

The Crucified Jesus; a Devotional Commentary on the XXII and XXIII Chapters of St. Luke. By A. Horneck, D.D. 3*d.*

Short Reflections for every Morning and Evening during the Week. By N. Spinckes, 2*d.*

The Sick Man Visited; or, Meditations and Prayers for the Sick Room. By N. Spinckes, 3*d.*

*** These are arranged together as being suitable for Private Meditation and Prayer: they may be had separately at the prices affixed.

Helps to Daily Devotion. 32mo. Cloth, 8*d.* Containing:—

The Sum of Christianity, 1*d.*

Directions for spending One Day Well, ½*d.*

Helps to Self-Examination, ½*d.*

Short Reflections for Morning and Evening, 2*d.*

Prayers for a Week, 2*d.*

The History of our Lord and Saviour Jesus Christ; in Three Parts, with suitable Meditations and Prayers. By W. Reading, M.A. 32mo. Cloth, 2*s.*; calf, gilt edges, 4*s.* Calf antique, 5*s.* 6*d.*

Hall's Sacred Aphorisms. Selected and arranged with the Texts to which they refer, by the Rev. R. B. Exton, M.A. 32mo. cloth, 9*d.*; limp calf, gilt edges, 2*s.* 3*d.*

Devout Musings on the Book of Psalms. 2 vols. 32mo. Cloth, 5*s.*; calf, gilt edges, 9*s.*; calf antique, 12*s.* Or, in four parts, price 1*s.* each; limp calf, gilt edges, 2*s.* 6*d.*

The Church Sunday School Hymn Book. 32mo. cloth, 8*d.*; calf, gilt edges, 2*s.* 6*d.*

*** A *Large Paper Edition* for Prizes, &c. 1*s.* 6*d.*; calf, gilt edges, 3*s.* 6*d.*

SHORT Meditations for Every Day in the Year. Edited by the Very Rev. W. F. Hook, D. D. *New Edition.* 4 vols. fcap. 8vo., large type, 14*s.*; morocco, 30*s.*

The Christian taught by the Church's Services. Edited by the Very Rev. W. F. Hook, D. D. *New Edition*, fcap. 8vo. large type. 6*s.* 6*d.* Antique calf, or morocco, 11*s.* 6*d.*

Holy Thoughts and Prayers, arranged for Daily Use on each Day of the Week, according to the stated Hours of Prayer. *Fifth Edition*, with additions. 16mo. Cloth, red edges, 2*s.*; calf, gilt edges, 3*s.*

A Companion to the Altar. Being Prayers, Thanksgivings, and Meditations, and the Office of the Holy Communion. Edited by the Very Rev. W. F. Hook, D.D. *Second Edition.* Handsomely printed in red and black. 32mo. Cloth, red edges, 2*s.* Morocco, 3*s.* 6*d.*

The Church Sunday School Hymn Book. Edited by W. F. Hook, D.D. *Large paper.* Cloth, 1*s.* 6*d.*; calf, gilt edges, 3*s.* 6*d.*

*** For cheap editions of the above Five Books, see List of the Devotional Library.

EDUCATIONAL BOOKS.

Bibliotheca Classica.

A Series of Greek and Latin Authors. With English Notes. 8vo. Edited by various Scholars, under the direction of G Long, Esq., M.A., Classical Lecturer of Brighton College: and the late Rev. A. J. Macleane, M.A., Head Master of King Edward's School, Bath.

AESCHYLUS. By F. A. Paley, M.A. 18*s.*

Cicero's Orations. Edited by G. Long, M.A. 4 vols. Vol. I. 16*s.*; Vol. II. 14*s*; Vol. III. 16*s.*; Vol. IV. 18*s.*

Demosthenes. By R. Whiston, M.A., Head Master of Rochester Grammar School. Vol. I. 16*s.* Vol. II. *preparing.*

Euripides. By F. A. Paley, M.A. 3 vols. 16*s.* each.

Herodotus. By J. W. Blakesley, B.D., late Fellow and Tutor of Trinity College, Cambridge. 2 vols. 32*s.*

Hesiod. By F. A. Paley, M.A. 10*s.* 6*d.*

Homer. By F. A. Paley, M. A. Vol. I. [*Preparing.*

Horace. By A. J. Macleane, M.A. 18*s.*

Juvenal and Persius. By A. J. Macleane, M.A. 14*s.*

Plato. By W. H. Thompson, M.A. Vol. I. [*Preparing.*

Sophocles. By F. H. Blaydes, M.A. Vol. I. 18*s.* Vol. II. *preparing.*

Terence. By E. St. J. Parry, M.A., Balliol College, Oxford. 18*s.*

Virgil. By J. Conington, M.A., Professor of Latin at Oxford. Vol. I. containing the Bucolics and Georgics. 12*s.* Vol. II. containing the Æneid, Books I. to VI. 14*s.* Vol. III. *preparing.*

Grammar-School Classics.

A Series of Greek and Latin Authors. Newly Edited, with English Notes for Schools. Fcap. 8vo.

C. CAESARIS Commentarii de Bello Gallico. *Second Edition.* By G. Long, M.A. 5*s.* 6*d.*

Caesar de Bello Gallico, Books 1 to 3. With English Notes for Junior Classes. By G. Long, M.A. 2*s.* 6*d.*

M. Tullii Ciceronis Cato Major, Sive de Senectute, Laelius, Sive de Amicitia, et Epistolae Selectae. By G. Long, M.A. 4*s.* 6*d.*

Quinti Horatii Flacci Opera Omnia. By A. J. Macleane, 6*s.* 6*d.*

Juvenalis Satirae XVI. By H. Prior, M.A. (Expurgated Edition.) 4*s.* 6*d.*

Grammar-School Classics continued.

P. Ovidii Nasonis Fastorum Libri Sex. By F. A. Paley. **5s.**

C. Sallustii Crispi Catilina et Jugurtha. By G. Long, M.A. **5s.**

Taciti Germania et Agricola. By P. Frost, M.A. **3s. 6d.**

Xenophontis Anabasis, with Introduction; Geographical and other Notes, Itinerary, and Three Maps compiled from recent surveys. By J. F. Macmichael, B.A. *New Edition.* 5s.

Xenophontis Cyropaedia. By G. M. Gorham, M.A., late Fellow of Trinity College, Cambridge. 6s.

Uniform with the above.

The New Testament in Greek. With English Notes and Prefaces by J. F. Macmichael, B.A. 730 pages. 7s. 6d.

Cambridge Greek and Latin Texts.

THIS series is intended to supply for the use of Schools and Students cheap and accurate editions of the Classics, which shall be superior in mechanical execution to the small German editions now current in this country, and more convenient in form.

The texts of the *Bibliotheca Classica* and *Grammar School Classics*, so far as they have been published, will be adopted. These editions have taken their place amongst scholars as valuable contributions to the Classical Literature of this country, and are admitted to be good examples of the judicious and practical nature of English scholarship; and as the editors have formed their texts from a careful examination of the best editions extant, it is believed that no texts better for general use can be found.

The volumes will be well printed at the Cambridge University Press, in a 16mo. size, and will be issued at short intervals.

AESCHYLUS, ex novissima recensione F. A. Paley. **3s.**

Cæsar de Bello Gallico, recensuit G. Long, A.M. **2s.**

Cicero de Senectute et de Amicitia et Epistolæ Selectæ, recensuit G. Long, A.M. 1s. 6d.

Euripides, ex recensione F. A. Paley, A. M. 3 vols. **3s. 6d.** each.

Herodotus, recensuit J. W. Blakesley, S.T.B. 2 vols. **7s.**

Horatius, ex recensione A. J. Macleane, A.M. **2s. 6d.**

Lucretius, recognovit H. A. J. Munro, A.M. **2s. 6d.**

Sallusti Crispi Catilina et Jugurtha, recognovit G. Long, A.M. 1s. 6d.

Thucydides, recensuit J. G. Donaldson, S.T.P. 2 vols. **7s.**

Vergilius, ex recensione J. Conington, A.M. **3s. 6d.**

Xenophontis Anabasis recensuit J. F. Macmichael, A.B. **2s. 6d.**

Novum Testamentum Graecum Textus Stephanici, 1550. Accedunt variae Lectiones editionum Bezae, Elzeviri, Lachmanni, Tischendorfii, Tregellesii, curante F. H. Scrivener, A.M. 4s. 6d.

Also, on 4to. writing paper, for MSS. notes. Half bound, gilt top, **12s.**

Foreign Classics.

With English Notes for Schools. Uniform with the GRAMMAR SCHOOL CLASSICS. Fcap. 8vo.

GERMAN Ballads from Uhland, Goethe, and Schiller, with Introductions to each Poem, copious Explanatory Notes, and Biographical Notices. Edited by C. L. Bielefeld. 3s. 6d.

Schiller's Wallenstein, complete Text. Edited by Dr. A. Buchheim. 6s 6d.

Picciola, by X. B. Saintine. Edited by Dr. Dubuc. *Second Edition, revised.* 3s. 6d.

This interesting story has been selected with the intention of providing for schools and young persons a good specimen of contemporary French literature, free from the solecisms which are frequently met with in writers of a past age.

Select Fables of La Fontaine. *Third Edition, revised.* Edited by F. Gasc, M.A. 3s.

" None need now be afraid to introduce this eminently French author, either on account of the difficulty of translating him, or the occasional licence of thought and expression in which he indulges. The renderings of idiomatic passages are unusually good, and the purity of English perfect."—*Athenæum.*

Histoire de Charles XII. par Voltaire. Edited by L. Direy. *Third Edition, revised.* 3s. 6d.

Aventures de Télémaque, par Fénélon. Edited by C. J. Delille. *Second Edition, revised.* 4s. 6d.

Classical Tables. 8vo.

NOTABILIA Quædam: or, the principal tenses of such Irregular Greek Verbs and such elementary Greek, Latin, and French Constructions as are of constant occurrence. 1s. 6d.

Greek Accidence. By the Rev. P. Frost, M.A. 1s.

Latin Accidence. By the Rev. P. Frost, M. A. 1s.

Latin Versification. 1s.

The Principles of Latin Syntax. 1s.

Homeric Dialect: its leading Forms and Peculiarities. By J. S. Baird, T.C.D. 1s. 6d.

A Catalogue of Greek Verbs, Irregular and Defective; their leading formations, tenses in use, and dialectic inflexions; with a copious Appendix, containing Paradigms for conjugation, Rules for formation of tenses, &c. &c. By J. S. Baird, T.C.D. *New Edition, revised.* 3s. 6d.

Richmond Rules to form the Ovidian Distich, &c. By J. Tate, M.A. *New Edition, revised.* 1s. 6d.

AN Atlas of Classical Geography, containing 24 Maps; constructed by W. Hughes, and edited by G. Long. *New Edition,* with coloured outlines, and an Index of Places. 12s. 6d.

A Grammar School Atlas of Classical Geography. The Maps constructed by W. Hughes, and edited by G. Long. Imp. 8vo. 5s.

First Classical Maps, with Chronological Tables of Grecian and Roman History, Tables of Jewish Chronology, and a Map of Palestine. By the Rev. J. Tate, M.A. *Third Edition.* Imp. 8vo. 7s. 6d.

Analecta Graeca Minora. With Introductory Sentences, English Notes, and a Dictionary. By the Rev. P. Frost, late Fellow of St. John's College, Cambridge. Fcap. 8vo. 3*s*. 6*d*.

Materials for Greek Prose Composition. By the Rev. P. Frost, M.A. Fcap. 8vo. 3*s*. 6*d*. Key, 5*s*.

Materials for Latin Prose Composition. By the Rev. P. Frost, M.A. *Third Edition.* 12mo. 2*s*. 6*d*. Key, 4*s*.

The Choephorae of Æschylus and Scholia. Revised and interpreted by J. F. Davies, Esq., B.A., Trin. Coll., Dublin. 8vo. 7*s*. 6*d*.

Auxilia Graeca: containing Forms of Parsing and Greek Trees, the Greek Prepositions, Rules of Accentuation, Greek Idioms, &c. &c. By the Rev. H. Fowler, M.A. 12mo. 3*s*. 6*d*.

Homer and English Metre. An Essay on the Translating of the Iliad and Odyssey. With a Literal Rendering in the Spenserian Stanza of the First Book of the Odyssey, and Specimens of the Iliad. By William G. T. Barter, Esq., Author of "A Literal Translation, in Spenserian Stanza, of the Iliad of Homer." Crown 8vo. 6*s*. 6*d*.

A Latin Grammar. By T. Hewitt Key, M.A., F.R.S., Professor of Comparative Grammar, and Head Master of the Junior School, in University College. *Third Edition, revised.* Post 8vo. 8*s*.

A Short Latin Grammar, for Schools. By T. H. Key, M.A., F.R.S. *Third Edition.* Post 8vo. 3*s*. 6*d*.

Latin Accidence. Consisting of the Forms, and intended to prepare boys for Key's Short Latin Grammar. Post 8vo. 2*s*.

A First Cheque Book for Latin Verse Makers. By the Rev. F. Gretton, Stamford Free Grammar School. 1*s*. 6*d*. Key, 2*s*. 6*d*.

Reddenda; or Passages with Parallel Hints for translation into Latin Prose and Verse. By the Rev. F. E. Gretton. Crown 8vo. 4*s*. 6*d*.

Rules for the Genders of Latin Nouns, and the Perfects and Su-pines of Verbs; with hints on Construing, &c. By H. Haines, M.A. 1*s*. 6*d*.

Latin Prose Lessons. By the Rev. A. Church, M.A., one of the Masters of Merchant Taylors' School. Fcap. 8vo. 2*s*. 6*d*.

The Works of Virgil, closely rendered into English Rhythm, and illustrated from British Poets of the 16th, 17th, and 18th Centuries. By the Rev. R. C. Singleton, M.A. 2 vols. post 8vo. 18*s*.

Quintus Horatius Flaccus. Illustrated with 50 Engravings from the Antique. Fcap. 8vo. 5*s*. Morocco, 9*s*.

Selections from Ovid: Amores, Tristia, Heroides, Metamorphoses. With English Notes, by the Rev. A. J. Macleane, M.A. Fcap. 8vo. 3*s*. 6*d*.

Sabrinae Corolla in hortulis Regiae Scholae Salopiensis con-texuerunt tres viri floribus legendis. *Editio Altera.* 8vo. 12*s*. Morocco, 21*s*.

Dual Arithmetic, a New Art, by Oliver Byrne, formerly Professor of Mathematics at the late College of Civil Engineers, Putney. 8vo. 10*s*. 6*d*.

A Graduated Series of Exercises in Elementary Algebra, with an Appendix containing Miscellaneous Examples. By the Rev. G. F. Wright, M.A., Mathematical Master at Wellington College. Crown 8vo. 3*s*. 6*d*.

The Elements of Euclid. Books I.—VI. XI. 1—21; XII. 1, 2; a new text, based on that of Simson, with Exercises. Edited by H. J. Hose, late Mathematical Master of Westminster School. Fcap. 4*s*. 6*d*.

A Graduated Series of Exercises on the Elements of Euclid: Books I.—VI.; XI. 1—21; XII. 1, 2. Selected and arranged by Henry J. Hose, M.A. 12mo. 1*s.*

The Enunciations and Figures belonging to the Propositions in the First Six and part of the Eleventh Books of Euclid's Elements, (usually read in the Universities,) prepared for Students in Geometry. By the Rev. J. Brasse, D.D. *New Edition.* Fcap. 8vo. 1*s.* On cards, in case, 5*s.* 6*d.*; without the Figures, 6*d.*

A Compendium of Facts and Formulæ in Pure and Mixed Mathematics. For the use of Mathematical Students. By G. R. Smalley, B.A., F.R.A.S. Fcap. 8vo. 3*s.* 6*d.*

A Table of Anti-Logarithms; containing to seven places of decimals, natural numbers, answering to all Logarithms from ·00001 to ·99999; and an improved table of Gauss' Logarithms, by which may be found the Logarithm of the sum or difference of two quantities. With an Appendix, containing a Table of Annuities for three Joint Lives at 3 per cent. Carlisle. By H. E. Filipowski. *Third Edition.* 8vo. 15*s.*

Handbook of the Slide Rule: showing its applicability to Arithmetic, including Interest and Annuities; Mensuration, including Land Surveying. With numerous Examples and useful Tables. By W. H. Bayley, H. M. East India Civil Service. 12mo. 6*s.*

The Mechanics of Construction; including the Theories on the Strength of Materials, Roofs, Arches, and Suspension Bridges. With numerous Examples. By Stephen Fenwick, Esq., of the Royal Military Academy, Woolwich. 8vo. 12*s.*

A New French Course, by Mons. F. E. A. Gasc, M.A.

FIRST French Book; being a New, Practical, and Easy Method of Learning the Elements of the French Language. *New Edition.* Fcap. 8vo. 1*s.* 6*d.*

French Fables, for Beginners, in Prose, with an Index of all the words at the end of the work. *New Edition.* Fcap. 8vo. 2*s.*

Second French Book; being a Grammar and Exercise Book, on a new and practical plan, and intended as a sequel to the "First French Book." *New Edition.* Fcap. 8vo. 2*s.* 6*d.*

A Key to the First and Second French Books. Fcap. 8vo. 3*s.* 6*d.*

Histoires Amusantes et Instructives; or, Selections of Complete Stories from the best French Modern Authors who have written for the Young. With English Notes. *New Edition.* Fcap. 8vo. 2*s.* 6*d.*

Practical Guide to Modern French Conversation: containing:— I. The most current and useful Phrases in Every-Day Talk; II. Everybody's Necessary Questions and Answers in Travel-Talk. *New Edition.* Fcap. 2*s.* 6*d.*

French Poetry for the Young. With English Notes, and preceded by a few plain Rules of French Prosody. Fcap. 8vo. 2*s.*

Materials for French Prose Composition; or, Selections from the best English Prose Writers. With copious Foot Notes, and Hints for Idiomatic Renderings. *New Edition.* Fcap. 8vo. 4*s.* 6*d.* Key, 6*s.*

Prosateurs Contemporains: or Selections in Prose, chiefly from contemporary French Literature. With English Notes. Fcap. 8vo. 5*s.*

Le Petit Compagnon: a French Talk-book for Little Children. With 52 Illustrations. 16mo. 2*s.* 6*d.*

THE French Drama; being a Selection of the best Tragedies and Comedies of Molière, Racine, P. Corneille, T. Corneille, and Voltaire. With Arguments in English at the head of each scene, and Notes, Critical and Explanatory, by A. Gombert. 18mo. Sold separately at 1*s.* each. Half-bound, 1*s.* 6*d.* each.

COMEDIES BY MOLIERE.

Le Misanthrope.	Les Précieuses Ridicules.
L'Avare.	L'Ecole des Femmes.
Le Bourgeois Gentilhomme.	L'Ecole des Maris.
Le Tartuffe.	Le Médecin Malgré Lui.
Le Malade Imaginaire.	M. de Pouceaugnac.
Les Femmes Savantes.	Amphitryon.
Les Fourberies de Scapin.	

TRAGEDIES, &c. BY RACINE.

La Thébaïde, ou les Frères Ennemis.	Bajazet.
Alexandre le Grand.	Mithridate.
Andromaque.	Iphigénie.
Les Plaideurs, (*Com.*)	Phèdre.
Britannicus.	Esther.
Bérénice.	Athalie.

TRAGEDIES, &c. BY P. CORNEILLE.

Le Cid.	Pompée.
Horace.	
Cinna.	BY T. CORNEILLE.
Polyeucte.	Ariane.

PLAYS BY VOLTAIRE.

Brutus.	Le Fanatisme.
Zaire.	Mérope.
Alzire.	La Mort de César.
Orestes.	Semiramis.

Le Nouveau Trésor: or, French Student's Companion: designed to facilitate the Translation of English into French at Sight. *Fifteenth Edition*, with Additions. By M. E*** S*****. 12mo. Roan, 3*s.* 6*d.*

A Test-Book for Students: Examination Papers for Students preparing for the Universities or for Appointments in the Army and Civil Service, and arranged for General Use in Schools. By the Rev. Thomas Stantial, M.A., Head Master of the Grammar School, Bridgwater. Part I.—History and Geography. 2*s.* 6*d.* Part II.—Language and Literature. 2*s.* 6*d.* Part III.—Mathematical Science. 2*s.* 6*d.* Part IV.—Physical Science. 1*s.* 6*d.* Or in 1 vol., Crown 8vo., 7*s.* 6*d.*

Tables of Comparative Chronology, illustrating the division of Universal History into Ancient, Mediæval, and Modern History; and containing a System of Combinations, distinguished by a particular type, to assist the Memory in retaining Dates. By W. E. Bickmore and the Rev. C. Bickmore, M.A. *Third Edition.* 4to. 5*s.*

A Course of Historical and Chronological Instruction. By W. E. Bickmore. 2 Parts. 12mo. 3*s.* 6*d.* each.

A Practical Synopsis of English History: or, A General Summary of Dates and Events for the use of Schools, Families, and Candidates for Public Examinations. By Arthur Bowes. *Fourth Edition.* 8vo. 2*s.*

Under Government: an Official Key to the Civil Service, and Guide for Candidates seeking Appointments under the Crown. By J. C. Parkinson, Inland Revenue, Somerset House. *Third Edition.* Cr. 8vo. 3s. 6d.

Government Examinations; being a Companion to "Under Government," and a Guide to the Civil Service Examinations. By J. C. Parkinson. Crown 8vo. 2s. 6d.

The Student's Text-Book of English and General History, from B.C. 100 to the present time. With Genealogical Tables, and a Sketch of the English Constitution. By D. Beale. *Sixth Edition.* Post 8vo. Sewed, 2s. Cloth, 2s. 6d.

"This is very much in advance of most works we have seen devoted to similar purposes. We can award very high praise to a volume which may prove invaluable to teachers and taught."—*Athenæum.*

The Elements of the English Language for Schools and Colleges. By Ernest Adams, Ph. D. University College School. *New Edition, enlarged, and improved.* Crown 8vo. 4s. 6d.

The Geographical Text-Book; a Practical Geography, calculated to facilitate the study of that useful science, by a constant reference to the Blank Maps. By M. E . . . S . . . . . *Second Edition.* 12mo. 2s.

II. The Blank Maps done up separately. 4to. 2s. coloured.

The Manual of Book-keeping; by an Experienced Clerk. 12mo. *Eighth Edition.* 4s.

Double Entry Elucidated. By B. W. Foster. *Eighth Edition.* 4to. 8s. 6d.

Penmanship, Theoretical and Practical, Illustrated and Explained. By B. F. Foster. 12mo. *New Edition.* 2s. 6d.

Goldsmith's (J.) Copy Books: five sorts, large, text, round, small, and mixed. Post 4to. on fine paper. 6s. per dozen.

The Young Ladies' School Record: or, Register of Studies and conduct. 12mo. 6d.

Welchman on the Thirty-nine Articles of the Church of England, with Scriptural Proofs, &c. 18mo. 2s. or interleaved for Students, 3s.

Bishop Jewel's Apology for the Church of England, with his famous Epistle on the Council of Trent, and a Memoir. 32mo. 2s.

A Short Explanation of the Epistles and Gospels of the Christian Year, with Questions for Schools. Royal 32mo. 2s. 6d.; calf, 4s. 6d.

Manual of Astronomy: a Popular Treatise on Descriptive, Physical, and Practical Astronomy. By John Drew, F.R.A.S. *Second Edition.* Fcap. 8vo. 5s.

The First Book of Botany. Being a Plain and Brief Introduction to that Science for Schools and Young Persons. By Mrs. Loudon. Illustrated with 36 Wood Engravings. *Second Edition.* 18mo. 1s.

English Poetry for Classical Schools; or, Florilegium Poeticum Anglicanum. 12mo. 1s. 6d.

Bell and Daldy's Illustrated School Books.

Royal 16mo.

SCHOOL Primer. 6*d*.

School Reader. [*Shortly*.

Poetry Book for Schools. 1*s*.

Old Testament History, in Simple Language. By the Rev. J. G. Wood, M.A. 1*s*. [*Ready*.

New Testament History, in Simple Language. By the Rev. J. G. Wood, M.A. [*Shortly*.

Course of Instruction for the Young, by Horace Grant.

EXERCISES for the Improvement of the Senses; for Young Children. 18mo. 1*s*. 6*d*.

Geography for Young Children. *New Edition*. 18mo. 2*s*.

Arithmetic for Young Children. *New Edition*. 18mo. 1*s*. 6*d*.

Arithmetic. Second Stage. *New Edition*. 18mo. 3*s*.

PERIODICALS.

THE Parish Magazine. Edited by J. Erskine Clarke, M.A., Derby. Monthly, price 1*d*. Volumes for 1859, 1860, 1861, and 1862, 1*s*. 6*d*. and 2*s*. each.

The Mission Field: a Monthly Record of the Proceedings of the Society for the Propagation of the Gospel. Vols. II. to VII. post 8vo. 3*s*. each. (Vol. I. is out of print.) Continued in Numbers, 2*d*. each.

The Gospel Missionary. Published for the Society for the Propagation of the Gospel in Foreign Parts, Monthly at ½*d*. Vols. II. to XII. in cloth, 1*s*. each. (Vol. I. is out of print.)

Missions to the Heathen; being Records of the Progress of the Efforts made by the Society for the Propagation of the Gospel in Foreign Parts for the Conversion of the Heathen. Published occasionally in a cheap form for distribution, at prices varying from 1*d*. to 1*s*. 6*d*. each. Nos. 1 to 43 are already published.

Church in the Colonies, consisting chiefly of Journals by the Colonial Bishops of their Progress and Special Visitations. Published occasionally at prices varying from 2*d*. to 1*s*. 6*d*. each. Nos. 1 to 37 are already published.

CLARKE'S COMMERCIAL COPY-BOOKS.

Price 4*d.* A liberal allowance to Schools and Colleges.

The First Copy-Book contains *elementary turns*, with a broad mark like a T, which divides a well-formed turn into two equal parts. This exercise enables the learner to judge of *form, distance, and proportion.*

The Second contains *large-hand letters*, and the means by which such letters may be properly combined; the joinings in writing being probably as difficult to learn as the form of each character. This book also gives the whole alphabet, not in separate letters, but rather as one *word;* and, at the end of the alphabet, the difficult letters are repeated so as to render the writing of the pupil more thorough and *uniform.*

The Third contains additional *large-hand practice.*

The Fourth contains *large-hand words*, commencing with *unflourished* capitals; and the words being short, the capitals in question receive the attention they demand. As Large, and Extra Large-text, to which the fingers of the learner are not equal, have been dispensed with in this series, the popular objection of having *too many Copy-books* for the pupil to drudge through, is now fairly met. When letters are very large, the scholar cannot compass them without stopping to change the position of his hand, which *destroys* the *freedom* which such writing is intended to promote.

The Fifth contains the essentials of a useful kind of *small-hand.* There are first, as in large-hand, five easy letters of the alphabet, forming four copies, which of course are repeated. Then follows the remainder of the alphabet, with the difficult characters alluded to. The letters in this hand, especially the *a, c, d, g, o,* and *q*, are so formed that when the learner will have to correspond, his writing will not appear stiff. The copies in this book are not *mere Large-hand reduced.*

The Sixth contains *small-hand copies*, with instructions as to the manner in which the pupil should hold his pen, so that when he leaves school he may not merely have some facility in copying, but really possess the information on the subject of writing which he may need at any future time.

The Seventh contains the foundation for a style of *small-hand*, adapted to females, *moderately pointed.*

The Eighth contains copies for females; and the holding of the pen is, of course, the subject to which they specially relate.

This Series is specially adapted for those who are preparing for a commercial life. It is generally found when a boy leaves school that his writing is of such a character that it is some months before it is available for book-keeping or accounts. The special object of this Series of Copy-Books is to form his writing in such a style that he may be put to the work of a counting-house at once. By following this course from the first the writing is kept free and legible, whilst it avoids unnecessary flourishing.

Specimens of hand-writing after a short course may be seen on application to the Publishers.

BELL AND DALDY'S

POCKET VOLUMES.

A SERIES OF SELECT WORKS OF FAVOURITE AUTHORS.

THE intention of the Publishers is to produce a Series of Volumes adapted for general reading, moderate in price, compact and elegant in form, and executed in a style fitting them to be permanently preserved.

They do not profess to compete with the so-called cheap volumes. They believe that a cheapness which is attained by the use of inferior type and paper, and absence of editorial care, and which results in volumes that no one cares to keep, is a false cheapness. They desire rather to produce books superior in quality, and relatively as cheap.

Each volume will be carefully revised by a competent editor, and printed at the Chiswick Press, on fine paper, with new type, and ornaments and initial letters specially designed for the series.

The *Pocket Volumes* will include all classes of Literature, both copyright and non-copyright;—Biography, History, Voyages, Travels, Poetry, sacred and secular, Books of Adventure and Fiction. They will include Translations of Foreign Books, and also such American Literature as may be considered worthy of adoption.

The Publishers desire to respect the moral claims of authors who cannot secure legal copyright in this country, and to remunerate equitably those whose works they may reprint.

The books will be issued at short intervals, in paper covers, at various prices, from 1*s.* to 3*s.* 6*d.*, and in cloth, top edge gilt, at 6*d.* per volume extra, in half morocco, Roxburgh style, at 1*s.* extra, in antique or best plain morocco (Hayday), at 4*s.* extra.

Now Ready.

Burns's Poems. 2*s.* 6*d.*
Burns's Songs. 2*s.* 6*d.*
Walton's Complete Angler. Illustrated. 2*s.* 6*d.*
Sea Songs and Ballads. By Charles Dibdin, and others. 2*s.* 6*d.*
White's Natural History of Selborne. 3*s.*
Coleridge's Poems. 2*s.* 6*d.*
The Robin Hood Ballads. 2*s.* 6*d.*
The Midshipman. By Capt. Basil Hall, R.N. 3*s.*
The Lieutenant and Commander. By the same Author. 3*s.*
Southey's Life of Nelson. 2*s.* 6*d.*
Longfellow's Poems. 2*s.* 6*d.*
Lamb's Tales from Shakspeare. 2*s.* 6*d.*
Milton's Paradise Lost. 2*s.* 6*d.*
George Herbert's Poems. 2*s.*
George Herbert's Works. 3*s.*
Milton's Paradise Regained and other Poems. 2*s.* 6*d.*

Preparing.

Walton's Lives of Donne, Wotton, Hooker, &c.
The Conquest of India. By Capt. Basil Hall, R.N.
Gray's Poems.
Goldsmith's Poems.
Goldsmith's Vicar of Wakefield.
Henry Vaughan's Poems.
And others.

CHISWICK PRESS:—PRINTED BY WHITTINGHAM AND WILKINS, TOOKS COURT, CHANCERY LANE.